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(54) **POLYMERIZED CATALYST COMPOSITION II**

(75) Inventors: **Stanley Wai-Yan Chow**, Sugarland, TX (US); **Guo-Xin Jin**, Shanghai (CN); **Zerong Lin**, Kingwood, TX (US); **Robert J. Wittenbrink**, Kingwood, TX (US); **Dao Zhang**, Changchun (CN)

(73) Assignee: **ExxonMobil Chemical Patents Inc.**, Houston, TX (US)

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(51) **Int. Cl.**
C08F 4/80 (2006.01)

(52) **U.S. Cl.** **526/172**; 526/135; 526/161; 526/184; 526/219.2; 526/219.3; 526/219.6; 526/227; 526/241; 526/147

(58) **Field of Classification Search** 526/135, 526/147, 161, 172, 184, 227, 241, 219.2, 526/219.3, 219.6

See application file for complete search history.

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(57) **ABSTRACT**

Copolymerization of Ni(II) phenol imine complexes containing olefinic substituents on aryl groups with styrene in the presence of a radical initiator results in polymerized late transition metal catalysts which can be used for olefin polymerization or oligomerization. These catalysts have high catalyst activity for olefin polymerization or oligomerization.

19 Claims, No Drawings

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POLYMERIZED CATALYST COMPOSITION

II

PRIORITY CLAIM AND RELATED
APPLICATIONS

This application claims priority from U.S. Ser. No. 60/434,913 filed Dec. 20, 2002; U.S. Ser. No. 60/435,228 filed Dec. 20, 2002 and U.S. Ser. No. 60/435,046 filed Dec. 20, 2002. This application is related to U.S. Ser. No. 60/421,282 filed Oct. 25, 2002; U.S. Ser. No. 60/421,163 filed Oct. 25, 2002; U.S. Ser. No. 60/421,164 filed Oct. 25, 2002; U.S. Ser. No. 60/433,934 filed Dec. 17, 2002; U.S. Ser. No. 60/434,082 filed Dec. 17, 2003 and U.S. Ser. No. 60/446,607 filed Feb. 12, 2003.

FIELD OF THE INVENTION

This invention relates to methods of polymerizing or oligomerizing one or more olefins, optionally with an activator, with one or more polymerized catalyst compounds prepared by polymerizing one or more free radical polymerizable monomers (such as styrene) with one or more different "single component" olefin polymerization catalyst precursors containing terminal unsaturation.

BACKGROUND

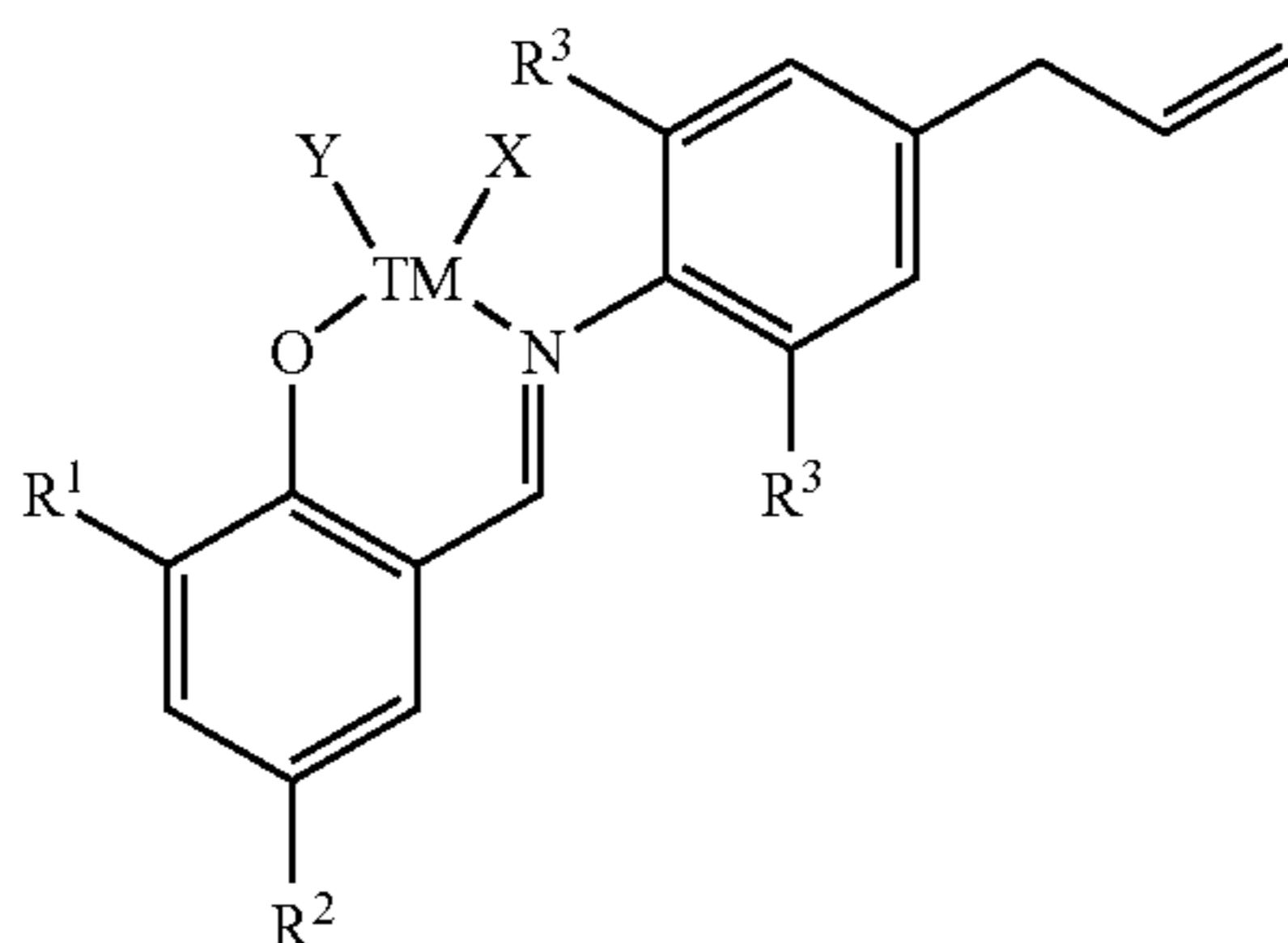
U.S. Pat. No. 5,714,425 describes metallocene catalyst compositions having a polymerizable olefinic group. These metallocenes are described as being useful to prepare polyolefins. In addition, these metallocenes are described as being polymerized with one or more alpha-olefins so that the metallocene is copolymerized with the alpha-olefin. This composition is then described as useful to polymerize olefins. But U.S. Pat. No. 5,714,4254 does not disclose free-radical polymerization of catalyst compositions having a polymerizable olefinic group with monomers such as styrene, isobutylene, 1,3-butadiene and the like.

U.S. Pat. No. 5,679,816 discloses bicyclopentadienyl transition-metal complexes containing a conjugated diene ligand group.

U.S. Pat. No. 6,150,544 and U.S. Pat. No. 6,352,953 disclose bimetallic, metallacyclic catalyst compounds where one metal is a Group-4 metal and the other metal is a Group-3 metal. (Likewise, it is also known in the art to prepolymerize a heterogeneous catalyst system in the presence of at least one olefin see EPA 426,646 and U.S. Pat. No. 4,871,705.)

SUMMARY

This invention relates to a composition comprising the product of combining, in the presence of a free radical initiator, one or more monomers that can be polymerized by a free radical initiator and a catalyst precursor represented by the formula:



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wherein X is a hydrocarbyl group or a halide, Y is a neutral Lewis base, and TM is any Group-4–11 metal, any Group-10 metal, or Ni. R¹, R², R³ and R⁴ are independently hydrogen or hydrocarbyl groups.

| R ¹ | R ² | R ³ , R ⁴ |
|-----------------|-----------------|---------------------------------|
| H | H | IPr |
| NO ₂ | NO ₂ | IPr |
| tBu | Me | IPr |
| Ph | H | IPr |
| Ph | H | Me |

This invention also relates to the above complex copolymerized with other molecules provided that the polymerization method is free-radical initiatable. This invention also relates to methods to polymerize olefins using the above compositions. These complexes alone or when copolymerized with other molecules are sometimes called catalyst systems.

DETAILED DESCRIPTION

Definitions

The term "hydrocarbyl radical" is sometimes used interchangeably with "hydrocarbyl" throughout this document. For purposes of this disclosure, "hydrocarbyl radical" encompasses C₁–C₂₀₀ radicals. These radicals can be linear, branched, or cyclic, and when cyclic, aromatic or non-aromatic. Thus, the term "hydrocarbyl radical", in addition to unsubstituted hydrocarbyl radicals, encompasses substituted hydrocarbyl radicals, halocarbyl radicals, and substituted halocarbyl radicals, as these terms are defined below.

Substituted hydrocarbyl radicals are radicals in which at least one hydrogen atom has been replaced with a functional group such as NRⁿ, ORⁿ, PRⁿ, SRⁿ, BRⁿ, SiRⁿ, GeRⁿ and the like or where at least one non-hydrocarbon atom or group has been inserted within the hydrocarbyl radical, such as O, S, NRⁿ, PRⁿ, BRⁿ, SiRⁿ, GeRⁿ, and the like, where Rⁿ is independently a C₁–C₃₀ hydrocarbyl or halocarbyl radical.

Halocarbyl radicals are radicals in which one or more hydrocarbyl hydrogen atoms have been substituted with at least one halogen or halogen-containing group (e.g. F, Cl, Br, I).

Substituted halocarbyl radicals are radicals in which at least one hydrocarbyl hydrogen or halogen atom has been substituted with a functional group such as NRⁿ, ORⁿ, PRⁿ, SRⁿ, BRⁿ, SiRⁿ, GeRⁿ and the like or where at least one non-carbon atom or group has been inserted within the halocarbyl radical such as O, S, NRⁿ, PRⁿ, BRⁿ, SiRⁿ, GeRⁿ, and the like where Rⁿ is independently a C₁–C₃₀ hydrocarbyl or halocarbyl radical provided that at least one halogen atom remains on the original halocarbyl radical.

In some embodiments, a hydrocarbyl radical is independently selected from methyl, ethyl, propyl, butyl, pentyl, hexyl, phenyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, eicosyl, heneicosyl, docosyl, tricosyl, tetracosyl, pentacosyl, hexacosyl, heptacosyl, octacosyl, nonacosyl, triacontyl, propenyl, butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decenyl, undecenyl, dodecenyl, tridecenyl, tetradecenyl, pentadecenyl, hexadecenyl, heptadecenyl, octadecenyl, nonadecenyl, eicosenyl, heneicosenyl, docosenyl, tricosenyl, tetracosenyl, pentacosenyl, hexacosenyl, heptacosenyl, octacosenyl, nonacosenyl, triacontenyl, propynyl, butynyl, pentynyl, hexynyl, heptynyl, octynyl,

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nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, eicosyl, heneicosyl, docosyl, tricosyl, tetracosyl, pentacosyl, hexacosyl, heptacosyl, octacosyl, nonacosyl, or triacontyl isomers. The radical may then be subjected to the types of substitutions described above. Also, terms like “propyl” and “hexyl” encompass all isomers, e.g. propyl means both n-propyl and isopropyl; hexyl includes all six carbon isomers including cyclic isomers.

Ancillary ligands serve to enforce the geometry around the metal center.

An “abstractable ligand” is a ligand that can be abstracted from the metal center by a cocatalyst leaving behind an activated catalyst.

For purposes of this disclosure oligomers have about 2–75 mer units. A mer is defined as a unit of an oligomer or polymer that originally corresponded to the monomer that was used in the polymerization reaction. For example, the mer of polyethylene would be ethylene.

In some structures throughout this specification, drawing the ligand-metal connection with an arrow, showing that the electrons for the bond originally came from the ligand, sometimes indicates coordination. At other times, drawing a solid line, showing the bond’s covalent nature, indicates coordination. One of ordinary skill in the art recognizes that these depictions are interchangeable.

The term “alkyl” or “alkyl radical” refer to branched or unbranched, saturated or unsaturated, acyclic hydrocarbyl radical. Suitable alkyl radicals include, for example, methyl, ethyl, n-propyl, i-propyl, 2-propenyl (or allyl), vinyl, n-butyl, t-butyl, i-butyl (or 2-methylpropyl). In particular embodiments, alkyls are C₁₋₂₀₀ hydrocarbyls, C₁₋₅₀ hydrocarbyls, or C₁₋₂₀ hydrocarbyls.

For purposes of this disclosure, “comprise” takes the meaning of “include”. When “include” is used, the disclosure intends the open construction of “include”. (The set including A, B, and C contains A, B, and C, but may also contain D, E, F, etc.)

Description

The inventive polymerized late transition metal catalyst precursors are prepared by copolymerizing transition metal phenolato complexes with an olefin such as styrene in the presence of a radical initiator (e.g., AIBN). These olefins are sometimes referred to in this document as catalyst polymerization monomer because they are the monomer that is used in polymerizing the catalyst. These complexes contain aryl groups that are substituted with polymerizable olefinic substituents. Divinyl benzene is optionally added to the copolymerization reaction medium to promote cross-linking.

Before polymerization into a co-polystyrene particle, the late transition metal catalyst precursors are sometimes simply called catalyst precursors. After polymerization, the catalyst precursors are sometimes called polymerized catalyst precursors. These catalyst precursors function in the presence of activators, but they are single component catalyst. This means that an activator is not necessary. These catalysts can polymerize olefins without using an activator to remove an abstractable ligand. Once active, the “polymerized catalyst precursors” are sometimes called polymerized catalysts.

Inventive transition metal complexes with olefinically substituted aryl groups are synthesized. Then they are free-radical copolymerized with an olefin. The resulting copolymer has units of polyolefin interspersed with enchain- ed catalyst molecules (catalyst precursors).

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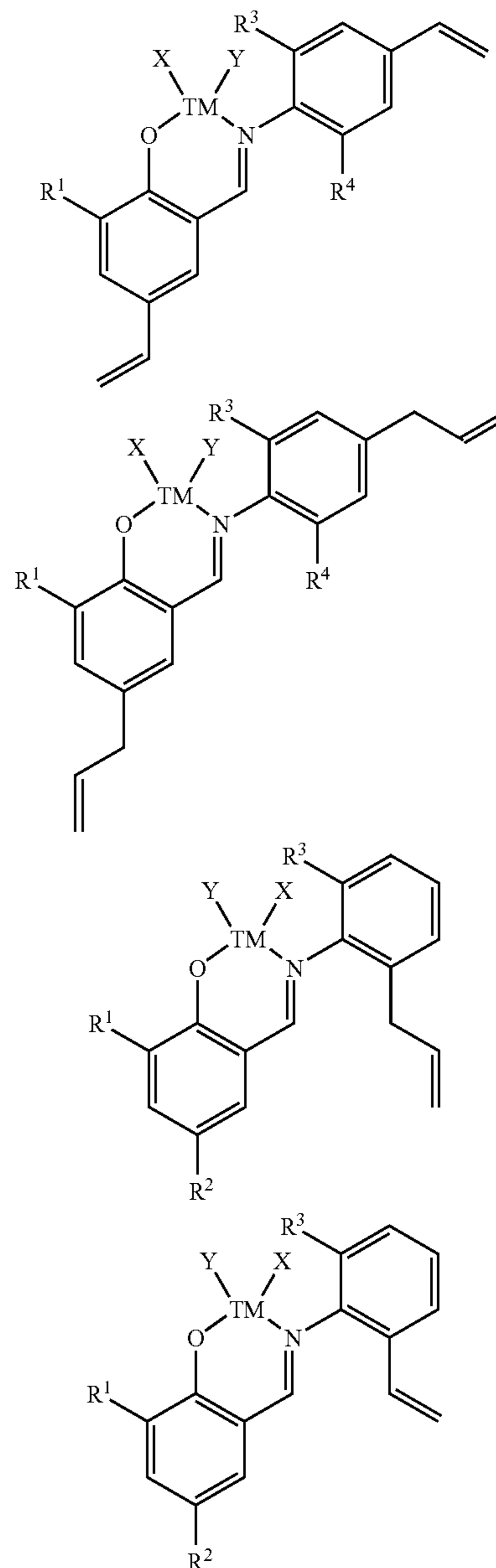
These enchain- ed complexes (catalyst precursors) function as ethylene or α -olefin polymerization or oligomerization catalysts. Ethylene or α -olefin monomers are sometimes referred to in this documents as olefin polymerization monomers because they represent the monomer or monomers that become polyolefins when combined with invention catalysts (as opposed to when invention catalyst precursors are subjected to free-radical initiation or polymerization). As shown in the Example section, aryl substituents other than the olefinic substituent sometimes affect catalyst performance.

Inventive late transition metal complexes are useful to prepare catalysts for olefin polymerization or oligomerization.

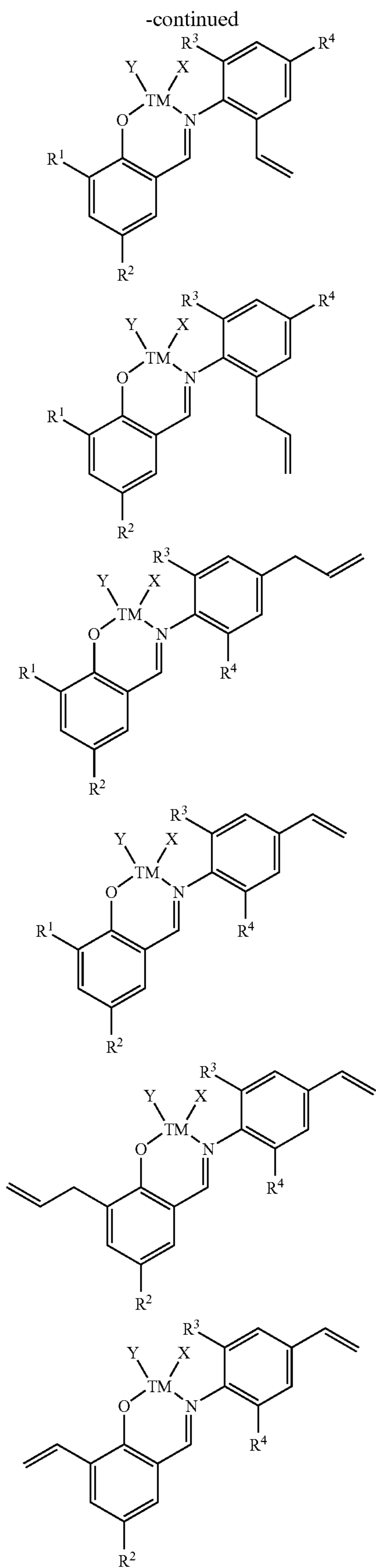
More than one catalyst precursor may be copolymerized with the monomers in varying ratios.

Catalyst Compounds

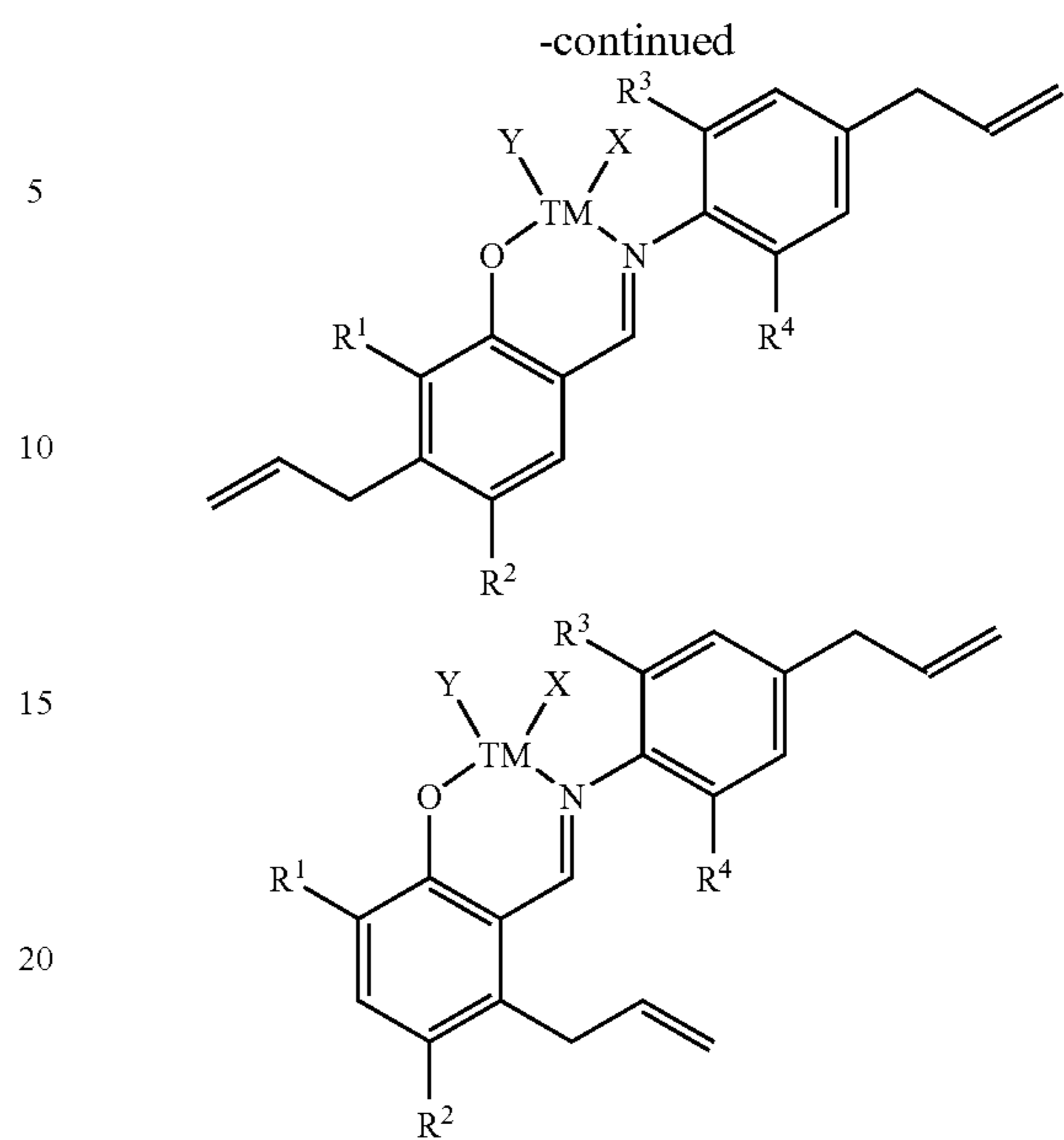
Catalyst compounds useful in this invention include those represented by the formulas:



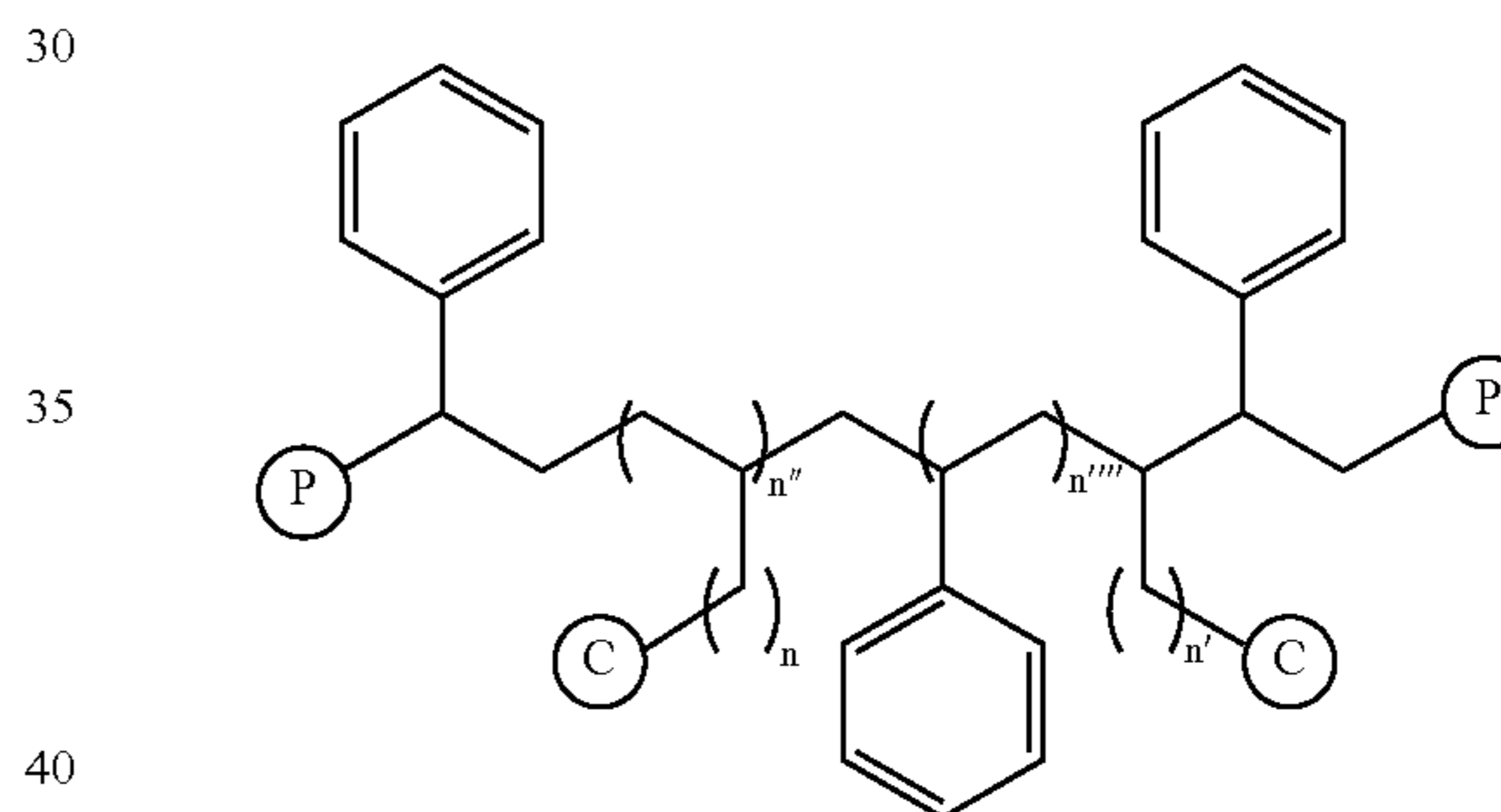
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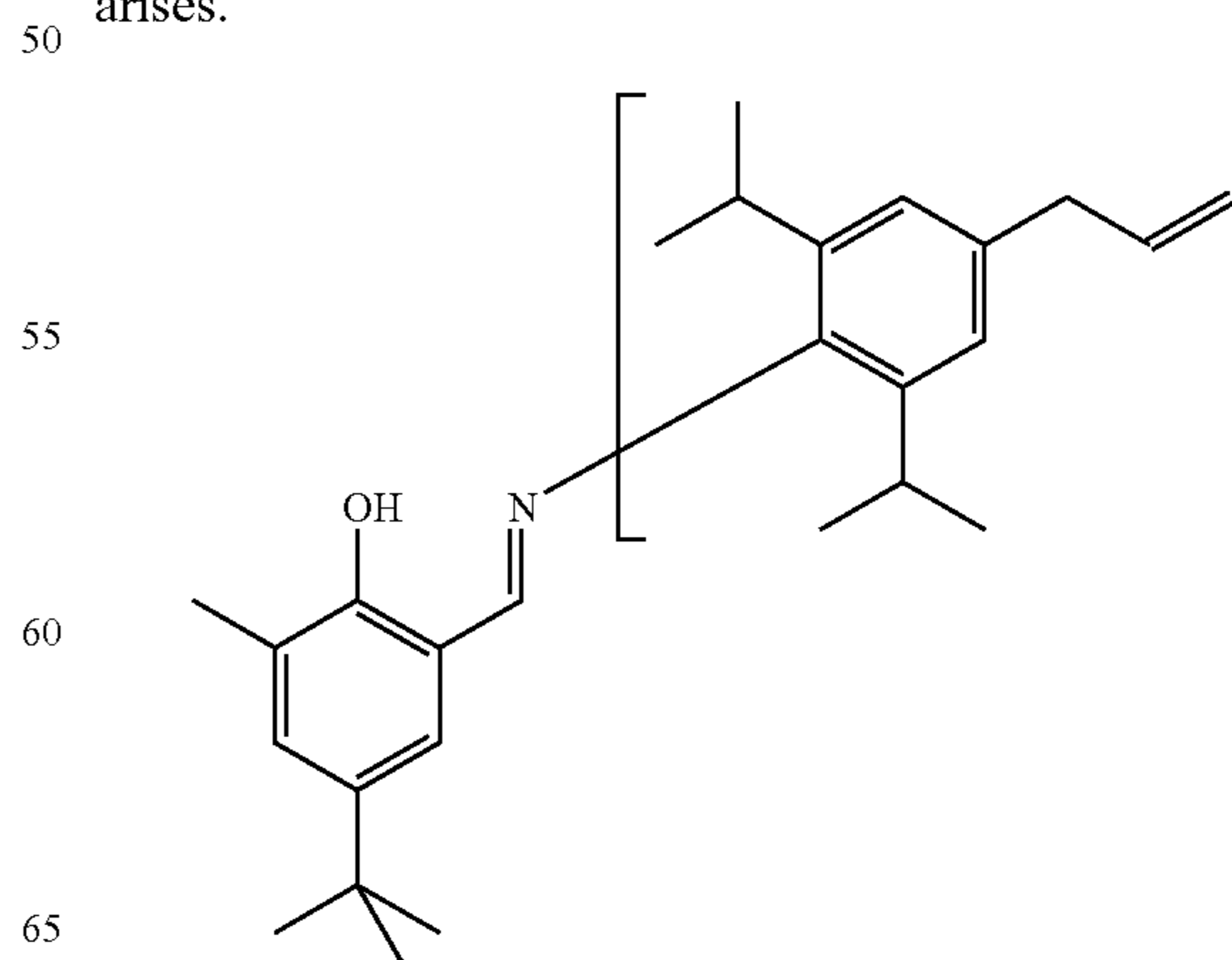


wherein X is a hydrocarbyl group or a halogen, particularly a halogen, particularly chlorine; Y is a neutral Lewis base, particularly triphenyl phosphine or acetonitrile; and M is any Group-4-11 metal, Group-10 metal, or Ni.



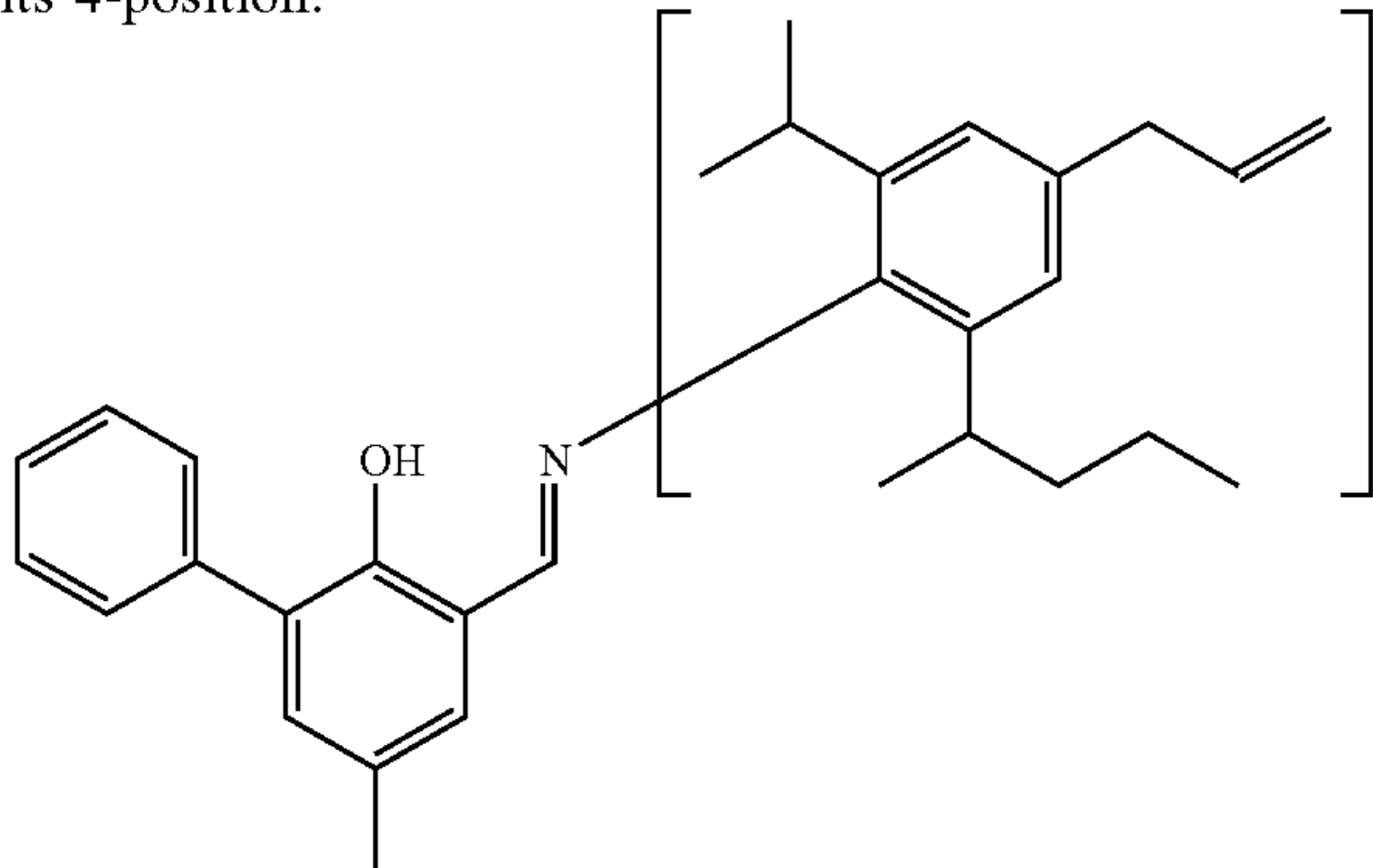
The above picture represents a schematic formula of the polymerized catalyst after polymerization. The P-labeled circles represent the bulk polyolefin/catalyst copolymer. The C-labeled circles represent the catalyst.

This section provides examples of how the ligands and complexes, as they exist before free-radical-initiated polymerization, are named and how the naming convention arises.



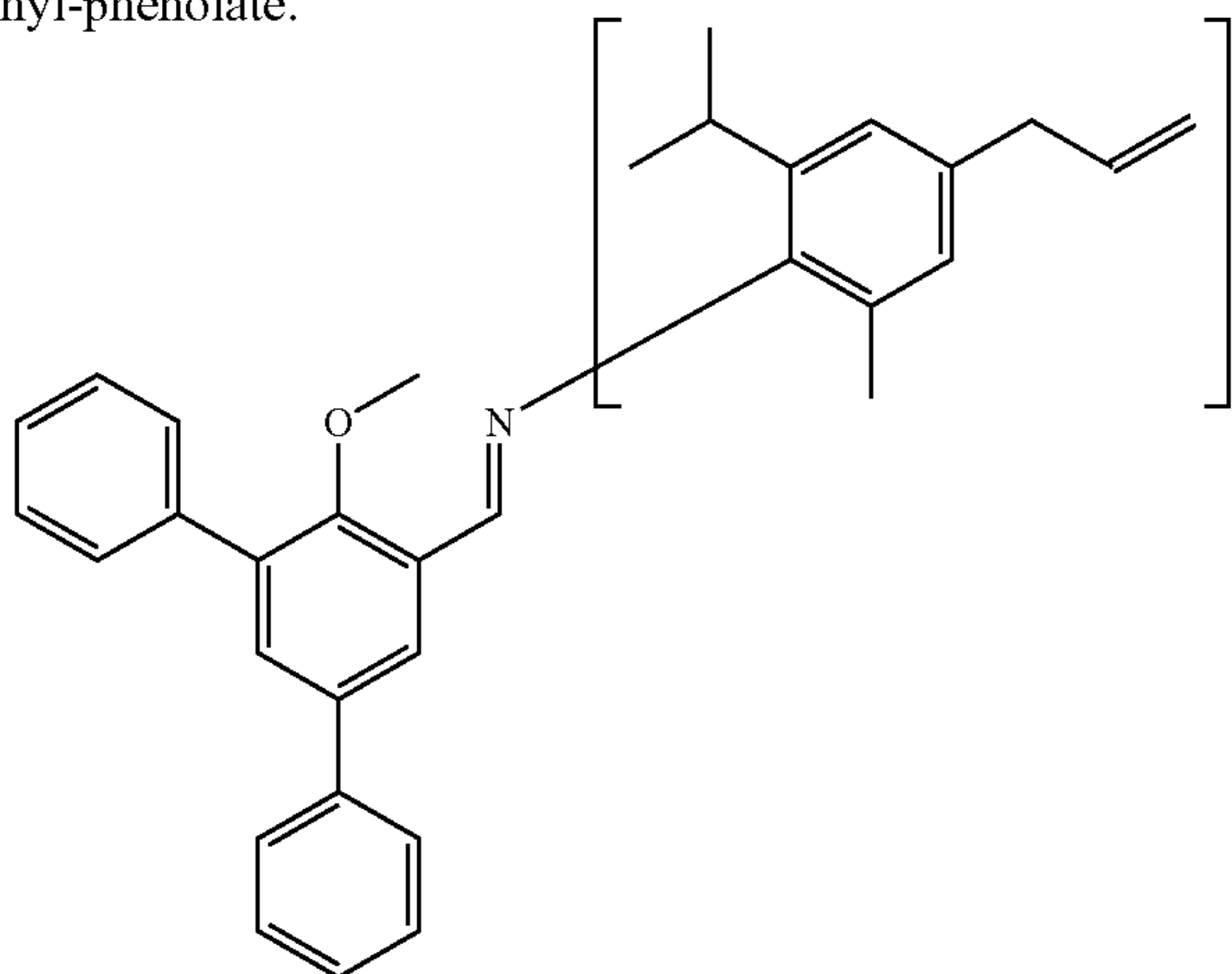
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The ligand pictured above is called 2-(2,6-diisopropyl-4-allylphenyliminomethyl)-4-tert-butyl-6-methyl-phenol. As is readily apparent, the ligand can be conceptualized as a trisubstituted phenol molecule. In this case, the phenol is substituted at the 4-position with a tertiary butyl radical. It is also substituted at the 6-position with a methyl radical. And the phenol ring 2-position is substituted with a substituted iminomethyl group. The substitution on the iminomethyl group is bracketed in the picture. This bracketed moiety is a substituted phenyl radical with isopropyl substitutions at its 2 and 6 positions and an allyl substitution at its 4-position.



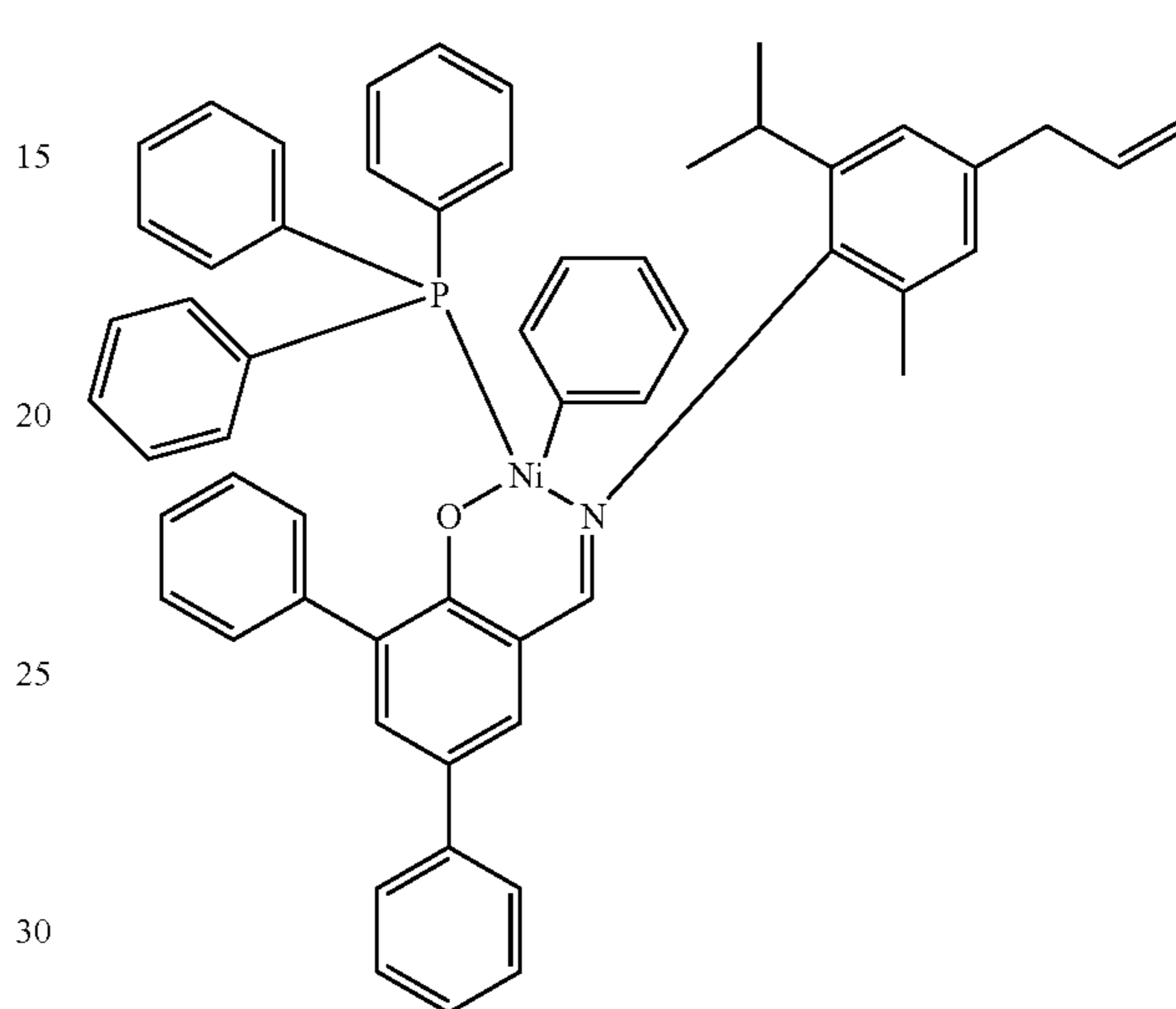
The ligand pictured above is called 2-(2-isopropyl-4-allyl-6-sec-pentylphenyliminomethyl)-4-methyl-6-phenyl-phenol. This ligand can also be conceptualized as a trisubstituted phenol molecule. In this case, the phenol is substituted at the 4-position with a methyl radical and substituted at the 6-position with a phenyl radical. As before, the phenol-ring 2-position is substituted with a substituted iminomethyl group. Once again, this iminomethyl group is bracketed in the picture. This bracketed moiety is a substituted phenyl radical with an isopropyl substitution at its 2-position, a secondary pentyl substitution at its 6-position, and an allyl substitution at its 4-position.

When these types of ligands are ionized by removing hydrogen from the phenol OH group, the ligands become bidentate, and can coordinate to an acceptor through the oxygen atom, the nitrogen atom, or both. For invention catalysts the acceptor is a transition metal. To indicate that the substituted phenol ligand is now acting as a radical, the phenol name receives a suffix, -ate, yielding phenolate. To indicate that the substituted phenol ligand is chelating, the phenolate name receives a suffix, -o, yielding phenolato. The ligand pictured below is shown ionized. It is called 2-(2-isopropyl-4-allyl-6-methylphenyliminomethyl)-4,6-diphenyl-phenolate.



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When the ligand above chelates or coordinates to a transition metal such as Ni, the complete name for the complex is 2-(2-isopropyl-4-allyl-6-methylphenyliminomethyl)-4,6-diphenyl-phenolato phenyl triphenylphosphine nickel (II). Note that the transition metal has a charged phenyl ligand and a neutral triphenylphosphine ligand (neutral Lewis base); one or both of these act as the abstractable ligand or leaving group. Thus, during olefin polymerization reactions with these complexes, either as shown or after their copolymerization with a styrenic monomer, the neutral Lewis base is believed to dissociate leaving behind a catalyst active for those reactions.



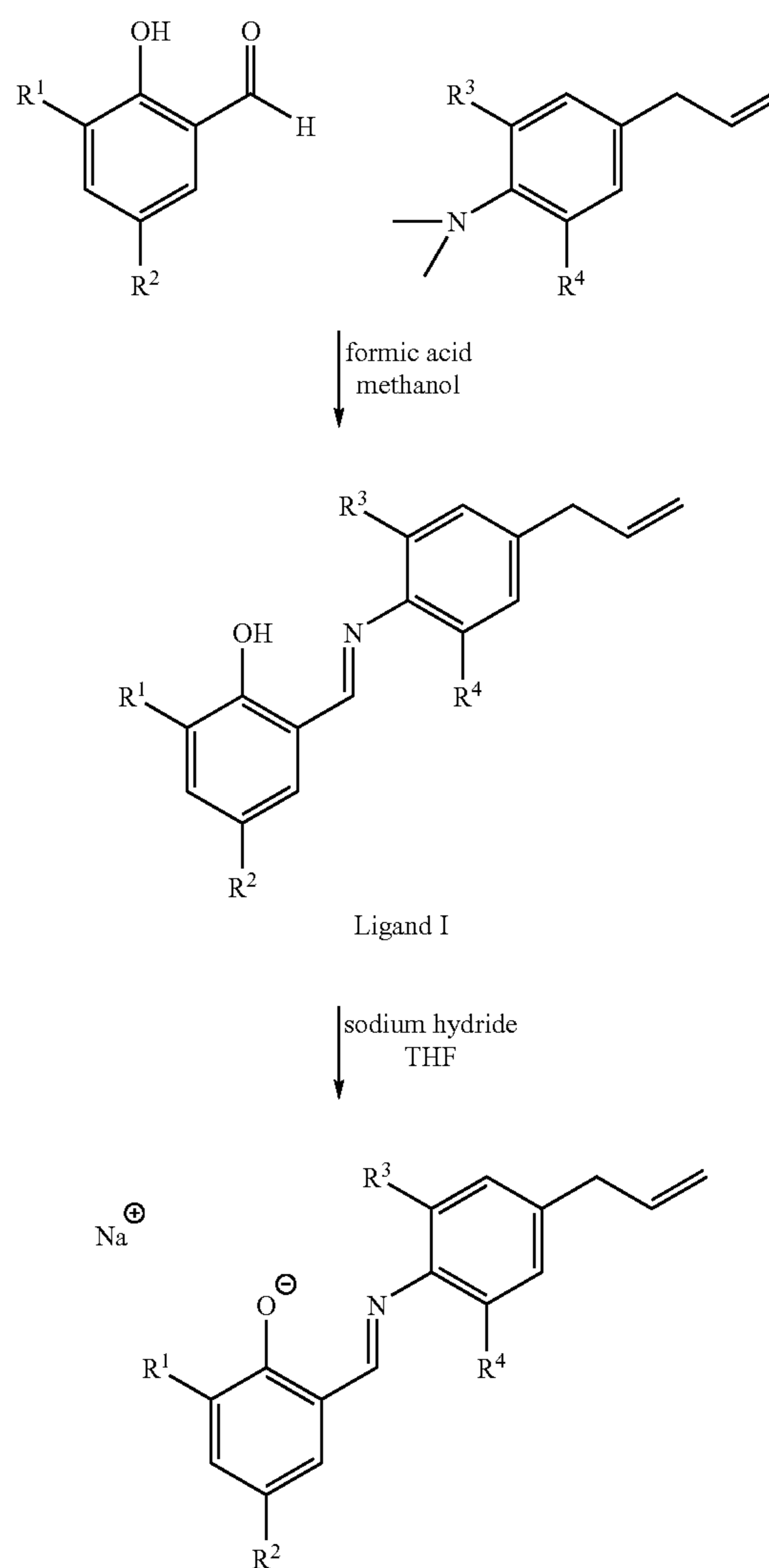
Useful Catalyst Compounds Include:

2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-6-propylphenolato phenyl trimethylamine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-hexyl-6-butylphenolato methyl dimethylethylamine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-phenyl-6-propylphenolato phenyl trimethylphosphine nickel (II); 2-(2,6-diheptadecyl-4-allyl-phenyliminomethyl)-4-propyl-6-ethylphenolato ethyl triethylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-6-phenylphenolato ethyl trimethylamine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-tridecyl-6-hexylphenolato phenyl triethylamine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-octylphenolato hydrido triethylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4,6-dimethylphenolato hydrido triethylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-octyl-6-phenylphenolato phenyl trimethylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-6-ethylphenolato methyl trimethylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-octyl-6-hexylphenolato phenyl triethylamine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-propyl-6-octylphenolato hydrido triethylamine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-phenyl-6-tetradecylphenolato ethyl trimethylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-ethylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4,6-diphenylphenolato hydrido triethylamine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-octyl-6-phenylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-dioctadecyl-4-allyl-phenyliminomethyl)-4-phenyl-6-ethylphenolato ethyl trimethylphosphine nickel (II); 2-(2,6-dipropyl-4-allyl-phenyliminomethyl)-4,6-dioctylphenolato methyl triethylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4,6-diphenyl-4-allyl-phenyliminomethyl-

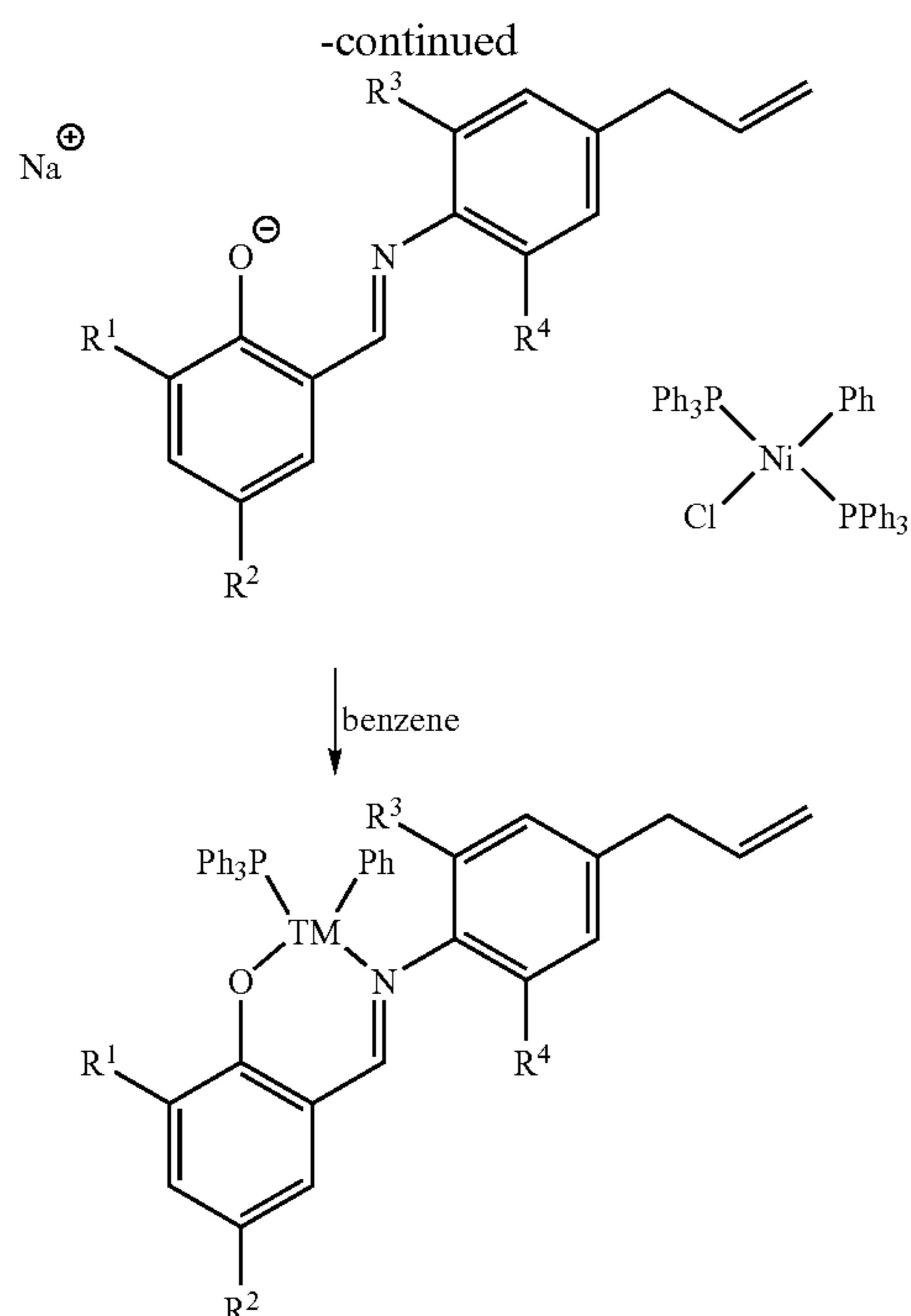
ethylphenolato iodo trimethylamine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-phenyl-6-hexylphenolato hydrido trimethylamine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-hexyl-6-methylphenolato hydrido triethylphosphine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-6-phenylphenolato hydrido trimethylamine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-4-phenyl-6-ethylphenolato hydrido methyldiethylphosphine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-6-octylphenolato iodo trimethylamine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4,6-dimethylphenolato hydrido triphenylphosphine nickel (II); 2-(2,6-ditetradecyl-4-allyl-phenyliminomethyl)-4-hexyl-6-propylphenolato hydrido triphenylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-phenyl-6-tetradecylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-dipropyl-4-allyl-phenyliminomethyl)-4-octadecyl-6-propylphenolato phenyl trimethylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-6-ethylphenolato ethyl triethylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-6-tetradecylphenolato hydrido methyldiethylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4,6-diphenylphenolato methyl trimethylphosphine nickel (II); 2-(2,6-dipentyl-4-allyl-phenyliminomethyl)-6-nonadecylphenolato hydrido triethylamine nickel (II); 2-(2,6-dipropyl-4-allyl-phenyliminomethyl)-4-ethyl-6-propylphenolato phenyl dimethylethylamine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-6-phenylphenolato methyl triethylamine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-6-hexylphenolato phenyl dimethylethylamine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-octyl-6-ethylphenolato phenyl triethylamine nickel (II); 2-(2,6-dioctadecyl-4-allyl-phenyliminomethyl)-4-propyl-6-phenylphenolato octyl triphenylamine nickel (II); 2-(2,6-dioctadecyl-4-allyl-phenyliminomethyl)-4-hexyl-6-ethylphenolato ethyl triethylphosphine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-4-nonyl-6-nonadecylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-phenylphenolato methyl triethylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-ethylphenolato methyl methyldiethylphosphine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-6-phenylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-dihexyl-4-allyl-phenyliminomethyl)-4-methylphenolato hydrido triphenylamine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-4-octyl-6-phenylphenolato methyl triethylamine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-octyl-6-phenylphenolato hydrido trimethylamine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4-octyl-6-phenylphenolato phenyl methyldiethylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-phenyl-6-hexylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-ethyl-6-octadecylphenolato phenyl triphenylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-octyl-6-phenylphenolato phenyl trimethylphosphine nickel (II); 2-(2,6-dihexyl-4-allyl-phenyliminomethylphenolato phenyl trimethylphosphine nickel (II); 2-(2,6-diethyl-4-allyl-phenyliminomethyl)-4-dodecyl-6-hexylphenolato hydrido triethylamine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4-phenylphenolato methyl trimethylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-6-methylphenolato hydrido trimethylphosphine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4-nonyl-6-phenylphenolato ethyl trimethylamine nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4,6-dihexylphenolato hydrido trimethylamine nickel (II); 2-(2,6-dinonyl-4-allyl-phenyliminomethyl)-4,6-dihexylphenolato hydrido triphenylphosphine

nickel (II); 2-(2,6-diphenyl-4-allyl-phenyliminomethyl)-4,6-dioctylphenolato phenyl triethylphosphine nickel (II); 2-(2,6-dihexyl-4-allyl-phenyliminomethyl)-4,6-diphenylphenolato hydrido trimethylamine nickel (II); 2-(2,6-dipentadecyl-4-allyl-phenyliminomethyl)-4,6-diundecylphenolato butyl trimethylamine nickel (II); 2-(2,6-dipropyl-4-allyl-phenyliminomethyl)-4,6-dimethylphenolato phenyl triethylamine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4,6-diphenylphenolato iodo dimethylethylamine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4,6-dihexylphenolato phenyl methyldiethylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethyl)-4,6-diethylphenolato phenyl triethylphosphine nickel (II); 2-(2,6-dimethyl-4-allyl-phenyliminomethylphenolato hydrido dimethylethylamine nickel (II); 2-(2,6-dipentadecyl-4-allyl-phenyliminomethyl)-4,6-dihexylphenolato butyl triethylphosphine nickel (II); 2-(2,6-dioctyl-4-allyl-phenyliminomethyl)-4,6-diphenylphenolato ethyl methyldiethylphosphine nickel (II); 2-(2,6-dihexyl-4-allyl-phenyliminomethylphenolato hydrido dimethylethylamine nickel (II); 2-(2,6-dipropyl-4-allyl-phenyliminomethyl)-4,6-dipropylphenolato phenyl triphenylphosphine nickel (II).

The catalyst compounds described above may be prepared according to Scheme I:



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The first step in preparing invention catalysts is to prepare the ancillary ligand. The ancillary ligand can be thought of as a substituted phenol. In Scheme I the phenol substituents are generic R^1 and R^2 and a substituted methyl radical that is substituted itself. The methyl radical is substituted with an imino group; the imino group is also substituted; substituted with a substituted phenyl group. When R^3 and R^4 are isopropyl, R^2 is hydrogen, and R^1 is phenyl, the ancillary ligand precursor shown in Scheme I (Ligand I) is called 2-(2,6-diisopropyl-4-allyl-phenyliminomethyl)-6-phenylphenol.

Synthesis of the ligand can occur through coupling its two main portions, the aniline and the aldehyde, such that an iminomethyl connection occurs. One way of accomplishing this is shown in Scheme I. The coupling reaction is the acid-catalyzed addition of an aniline to the benzaldehyde carbonyl group (with the loss of water).

Once the two main ligand portions are connected, synthesis of the ancillary ligand is complete. After this, the ligand is reduced and then simply complexed with an appropriate transition metal halide by mixing the halide and the ligand together. The overall name of the catalyst complex before it is copolymerized with an olefinic monomer is 2-(2,6-diisopropyl-4-allyl-phenyliminomethyl)-6-phenylphenolato phenyl triphenylphosphine nickel (II). Those of ordinary skill in the art will recognize that other synthetic pathways exist for making these ligands

Process to Prepare the Polymerized Catalyst Compounds

The catalyst precursor described above is then contacted with a free radical initiator and one or more monomers that can be polymerized by a free radical initiator. This yields a copolymer containing the phenolato-based olefin polymerization catalyst precursor.

A typical transition metal catalyst can be polymerized using the following procedure. 50 ml of a toluene solution with the terminal-unsaturation-containing catalyst, styrene, and AIBN are maintained at 80°C . for 7 hrs. The resulting solution is evaporated and the residue is washed with a

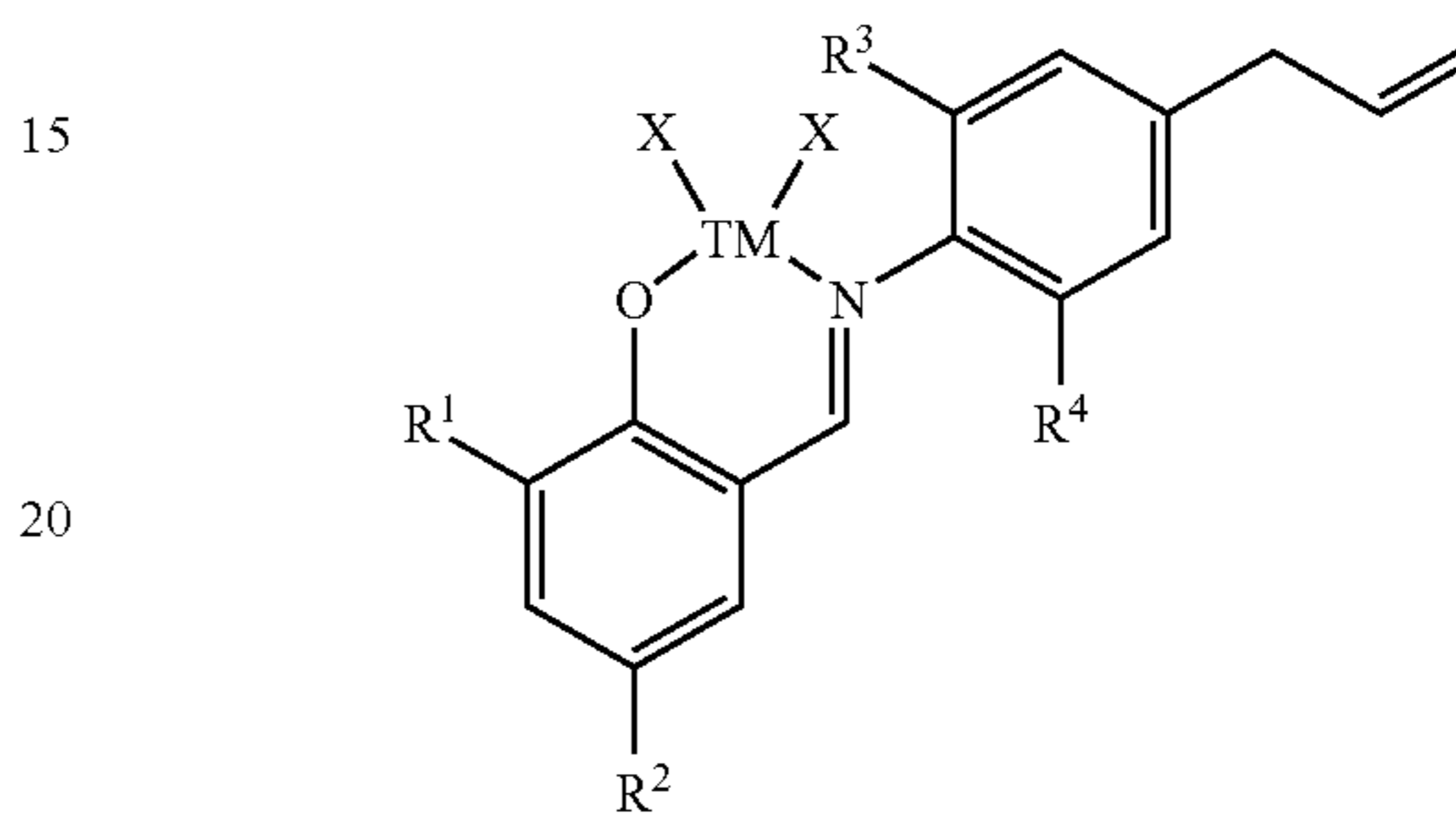
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mixture of hexane and toluene (2:1) and dried. Then, the solid polymer product is collected. Analogous methods yield the other disclosed polymerized catalysts.

The polymerization typically takes place in solution at a temperature of $30\text{--}100^\circ\text{C}$., $50\text{--}90^\circ\text{C}$., $70\text{--}85^\circ\text{C}$., or $75\text{--}85^\circ\text{C}$. Suitable solvents include toluene, benzene, xylene, and hexane. Desired solvents are selected from those that can dissolve the terminal-unsaturation-containing catalyst.

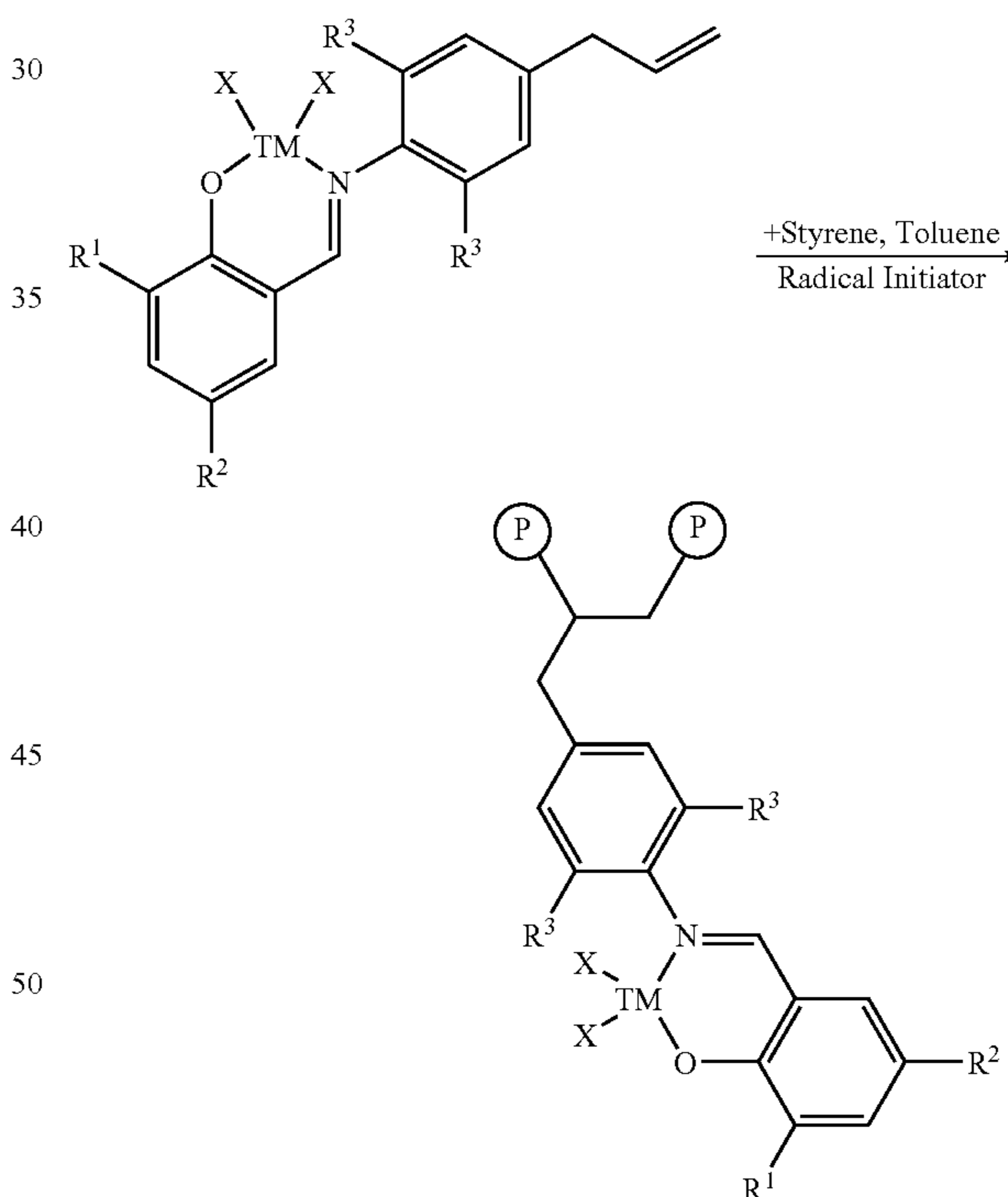
The polymerization may be performed at atmospheric, sub-atmospheric or super-atmospheric pressures.

Generally, the structure of a catalyst will look like this before copolymerization.



Scheme II illustrates the catalyst polymerization.

Scheme II



The polymerized catalyst compounds typically have Mw of up to 300,000; 500–150,000; 1,000–100,000; 5,000–75,000; or 10,000–50,000.

Free Radical Initiators

Free radical initiators that are useful in this invention include: (1) thermally decomposable compounds that generate radicals such as azo compounds or organic peroxides; (2) compounds that generate free radicals by non-thermal methods such as photochemical or redox processes; (3)

compounds that have inherent radical character such as molecular oxygen; or (4) electromagnetic radiation such as X-rays, electron beams, visible light and ultraviolet-light. Suitable organic peroxide compounds include hydroperoxides, dialkyl peroxides, diacyl peroxides, peroxyesters, peroxydicarbonates, peroxyketals, ketone peroxides and organosulfonyl peroxides. Especially preferred peroxides are t-butyl perbenzoate, dicumyl peroxide, 2,5-dimethyl-2,5-di-tert-butylperoxy-3-hexyne (Lupersol 130), α,α -bis(tert-butylperoxy)diisopropyl benzene (VulCup R).

Any free radical initiator or mixture having a 10-hour half-life temperature over 80° C. or their mixtures may function as the initiator in invention processes to prepare supported polymerized catalyst compounds. Generally, the higher the decomposition temperature of the peroxygen compound the better. See pages 66–67 of Modern Plastics, November 1971 for a more complete list of these compounds.

In one embodiment, the free radical initiator is an organic peroxide compound having a half-life, at the reaction temperature, of less than one tenth of the reaction/residence time employed. The free radical initiator is used at concentrations of 1–5% weight percent based on styrene (or other monomer).

The following classes and examples of free-radical initiators are useful in polymerizing invention terminal-unsaturation-containing catalyst precursors.

| | | | |
|-------------------|----------------------------|---|-----------------------|
| Azo initiators | Dialkyldiazenes | 2,2'-azobis(2-methylpropanenitrile) (AIBN) | |
| | | 1,1-azobis(1-cyclohexanenitrile) | |
| Peroxides | Hyponitrites | 4,4'-azobis(4-cyanovaleric acid) | |
| | | riphenylmethylazobenzene di-t-butyl hyponitrite | |
| | diacyl peroxides | Dicumyl hyponitrite | |
| | | Dibenzoyl peroxide | |
| | | Didodecanoyl peroxide | |
| | | Diacetyl peroxide | |
| | Dialkyl peroxydicarbonates | Diisopropyl ester | |
| | | Dicyclohexyl ester | |
| | Peresters | alkyl hydroperoxides | Cumyl hydroperoxide |
| | | | t-butyl hydroperoxide |
| dialkyl peroxides | inorganic peroxides | Dicumyl peroxide | |
| | | di-t-butyl peroxide | |
| | | Hydrogen peroxide | |
| | | persulfate | |

Monomers Polymerizable by a Free Radical Initiator

Monomers that can be polymerized by a free radical process include ethylene, 1,3-butadiene, isoprene, styrene, alkyl styrene, isobutylene, vinyl chloride, vinylidene chloride, vinyl fluoride, tetrafluoroethylene, vinyl esters, acrylic esters, methacrylic esters, acrylonitrile, and propylene. Therefore, any of these can be copolymerized with the catalyst compound containing the terminal unsaturation. For example, selecting isoprene for copolymerization results in a catalyst/isoprene copolymer.

Process to Polymerize Olefins Using Polymerized Catalyst Compounds

Some of the catalyst systems described above are suitable for use in solution polymerization processes, some for use in

gas-phase processes, and some in slurry processes. Some of the catalyst systems above are suitable for use in combinations of those processes.

In invention polymerization or oligomerization processes using invention catalyst systems, the process temperature can be –100° C. to 300° C., –20° C. to 200° C., or 0° C. to 150° C. Given one of these temperature ranges, the following ethylene oligomerization pressures (gauge) are useful: 0 kPa–35000 kPa or 500 kPa–15000 kPa.

In polymerization or oligomerization processes using invention catalyst systems and any of the process conditions described above, whether the selected process is solution, slurry, gas-phase or an amalgamation of these, the process can employ one or more, C_2 – C_{30} monomers. Alternatively, C_2 – C_{12} or C_2 – C_8 monomers are suitable. Specific examples of invention-suitable monomers include one or more of ethylene, propylene, butene-1, pentene-1, 4-methyl-pentene-1, hexene-1, octene-1, decene-1, 3-methyl-pentene-1, and cyclic olefins, or their combinations. Other monomers can include vinyl monomers, diolefins such as dienes, polyenes, norbornene, norbornadiene, vinyl norbornene, ethylidene norbornene monomers. Alternatively, invention polymerization processes produce homopolymers or copolymers of ethylene or propylene.

In polymerization or oligomerization processes using invention catalyst systems and any of the process conditions described above, polymerization with ethylene and at least two different comonomers forms terpolymers. Invention comonomers comprise a combination of any of the monomers described above or of C_2 – C_{30} or C_4 – C_8 , α -olefin monomers, optionally with at least one diene monomer. Terpolymers include combinations such as propylene/but-1-ene/hex-1-ene, propylene/but-1-ene/ethylene, propylene/ethylene/hex-1-ene, propylene/butene/norbornene, propylene/butene/decadiene, and the like. For purposes of this disclosure, nomenclature such as “but-1-ene”, which indicates that the olefinic unsaturation in the butene molecule begins at the first atom in the butene carbon chain, is equivalent to “butene-1”.

Invention oligomerization or polymerization processes can be run in the presence of various liquids, particularly aprotic organic liquids. In some embodiments the catalyst system is insoluble in most solvents; and thus, the polymerization will be slurry phase rather than solution phase. Liquid-suitable invention catalyst systems include alkanes, alkenes, cycloalkanes, selected halogenated hydrocarbons, aromatic hydrocarbons, and in some cases, hydrofluorocarbons as the solvent. Useful solvents specifically include hexane, toluene, cyclohexane, and benzene.

Gas-phase Polymerization

In polymerization or oligomerization processes using invention catalyst systems, the reactor pressure in a gas-phase process can vary from 69–3500 kPa, alternatively from 690 kPa–3500 kPa, from 1379 kPa–2800 kPa, or from 1700–2414 kPa. Invention processes and catalyst systems can use suitable gas-phase polymerization processes; some of these processes are described below.

In gas-phase polymerization or oligomerization processes using invention catalyst systems, given a particular reactor pressure range, the reactor temperature can vary from 30–120° C., alternatively from 60–115° C., from 70–110° C., or from 70–95° C. The reactor temperature is typically between 70–105° C. for high-density polyethylene.

In gas-phase polymerization or oligomerization processes using invention catalyst systems, monomer partial pressure

influences catalyst system productivity. Primary monomer concentration, such as ethylene or propylene, is from 25–90 mole percent, and its partial pressure is from 138–517 kPa or 517–2100 kPa. These conditions suit invention gas-phase polymerization or oligomerization processes. Also, in some systems, comonomer increases productivity.

Gas-phase polymerization or oligomerization processes using invention catalyst systems can produce 227–90,900 kg/hr of polymer, alternatively, 227–455 kg/hr, 227–4540 kg/hr, 227–11,300 kg/hr, 227–15,900 kg/hr, 227–22,700 kg/hr, and alternatively 29,000 kg/hr–45,500 kg/hr, or 45,500 kg/hr or more.

Gas-phase polymerization or oligomerization processes using invention catalyst systems can use the processes described in U.S. Pat. Nos. 5,627,242, 5,665,818 and 5,677,375, and European publications EP-A-0 794 200, EP-A-0 802 202 and EP-B-634 421.

In some gas-phase polymerization or oligomerization processes using invention catalyst systems, the reactor receives the liquid or solution catalyst system in its liquid form at a resin-particle-lean zone. For information on how to introduce a liquid catalyst system into a fluidized bed polymerization reactor at a resin-particle-lean zone, see U.S. Pat. No. 5,693,727.

Gas-phase polymerization or oligomerization processes using invention catalyst systems can operate with scavengers. Typical scavengers include trimethyl aluminum, triisobutyl aluminum, an excess of alumoxane or modified alumoxane, triethylaluminum, tri-n-hexylaluminum, diethyl aluminum chloride, dibutyl zinc and the like. PCT publication WO 96/08520 and U.S. Pat. No. 5,712,352 describe processes using these scavengers. Invention, gas-phase processes or catalyst systems can use these processes. Alternatively, gas-phase polymerization or oligomerization processes using invention catalyst systems can operate in the absence of or essentially free of scavengers.

Slurry Polymerization

In polymerization or oligomerization processes using invention catalyst systems, slurry polymerization processes generally use pressures of 103–5068 kPa gauge and temperatures of 0–120° C. Invention processes and catalyst systems can use suitable slurry polymerization processes; some of these processes are described below.

Typically, in a slurry polymerization, a suspension of solid, particulate polymer forms in a liquid polymerization medium to which ethylene (or α -olefinic monomer), (optional) comonomer, and catalyst, has been added. This suspension intermittently or continuously discharges from the reactor, after which the process separates the polymer from the volatile components and recycles them to the reactor (optionally after a distillation). The liquid employed in the polymerization medium typically comprises a C_3 – C_7 alkane, alternatively a branched alkane. The medium should be liquid and relatively inert under the polymerization conditions. For propane media, process temperatures and pressures are usually above the media's critical temperature and pressure. The processes can use hexane or isobutane media, as well.

One slurry polymerization process is a particle-form polymerization. It is a process where the temperature remains below the temperature at which the polymer appreciably dissolves in the reaction medium. Such techniques are well known in the art. U.S. Pat. No. 3,248,179. Particle-form process temperatures range from 85° C.–110° C. Two other slurry polymerization varieties employ a loop reactor or a

plurality of stirred reactors in series, parallel, or combinations thereof. These reactors can have cooling or not and can employ refrigerated or unrefrigerated monomer feeds. Non-limiting examples of slurry processes include continuous-loop and stirred-tank processes. Also, U.S. Pat. No. 4,613,484 describes other examples of slurry processes.

Slurry processes can use a continuous-loop reactor. The process regularly injects the catalyst, as a slurry in a compatible solvent or as a dry, free-flowing powder, into the reactor loop. The loop contains a circulating slurry of growing polymer particles in a diluent of isobutane containing monomer and comonomer. If desired, this process can control molecular weight with hydrogen. The reactor is maintained at a pressure of 3.620–4.309 MPa and at a temperature of 60–104° C. depending on the desired polymer density. Reaction heat is removed from the reactor through the loop wall since much of the reactor vessel is a double-jacketed pipe. The slurry discharges from the reactor at regular intervals or continuously. It discharges into a heated, low-pressure flash vessel, rotary dryer, and nitrogen purge column, in sequence, to remove isobutane diluent and all unreacted monomer and comonomer. The resulting hydrocarbon-free powder is then compounded for use in various applications.

Polymerization or oligomerization processes using invention catalyst systems and using slurry polymerization conditions can produce 1–100,000 kg polymer/hr, 907–100,000 kg/hr, 2268–100,000 kg/hr, 4540–100,000 kg/hr, 6804–100,000 kg/hr, 11,340–100,000 kg/hr, or 45,500–100,000 kg/hr.

Polymerization or oligomerization processes using invention catalyst systems and using slurry polymerization conditions can use total reactor pressures in the range of 2758–5516 kPa, 3103–4827 kPa, 3448–4482 kPa, or 3620–4309 kPa.

Polymerization or oligomerization processes using invention catalyst systems and using slurry polymerization conditions can use concentrations of predominant monomer in the reactor liquid medium of 1–10 wt %, 2–7 wt %, 2.5–6 wt %, or 3–6 wt %.

As with gas-phase polymerization conditions, polymerization or oligomerization processes using invention catalyst systems and slurry polymerization conditions can use slurry process variants that include or exclude scavengers.

Applications of Invention Polyolefins

Invention processes prepare homo- and co-polymer polyethylene useful for formulating adhesives and other materials. The terms invention polymers or invention copolymers refer to polymers made with invention catalysts or catalyst systems.

Formulations

In some embodiments, the polymer produced by this invention may be blended with one or more other polymers such as thermoplastic polymer(s) and elastomer(s).

A thermoplastic polymer is a polymer that can be melted by heating and then cooled without appreciable change in properties. Thermoplastic polymers typically include polyolefins, polyamides, polyesters, polycarbonates, polysulfones, polyacetals, polylactones, acrylonitrile-butadiene-styrene resins, polyphenylene oxide, polyphenylene sulfide, styrene-acrylonitrile resins, styrene maleic anhydride, polyimides, aromatic polyketones, or mixtures of two or more of the above. Specific polyolefins include polymers comprising one or more, linear, branched, or cyclic, C_2 – C_{40} olefins,

preferably polymers comprising ethylene or propylene copolymerized with one or more, C₃-C₄₀ olefins, C₃-C₂₀ α-olefins, or C₃-C₁₀ α-olefins.

Elastomers include all natural and synthetic rubbers, including those defined in ASTM D1566. Examples of elastomers include ethylene propylene rubber, ethylene propylene diene monomer rubber, styrenic block copolymer rubbers (including SI, SIS, SB, SBS, SIBS and the like, where S=styrene, I=isobutylene, and B=butadiene), butyl rubber, halobutyl rubber, copolymers of isobutylene and para-alkylstyrene, halogenated copolymers of isobutylene and para-alkylstyrene, natural rubber, polyisoprene, copolymers of butadiene with acrylonitrile, polychloroprene, alkyl acrylate rubber, chlorinated isoprene rubber, acrylonitrile chlorinated isoprene rubber, polybutadiene rubber (both cis and trans).

In another embodiment polymer produced by this invention is combined with one or more isotactic polypropylenes; highly isotactic polypropylenes; syndiotactic polypropylenes; random copolymers of propylene and ethylene or butene or hexene; polybutenes; ethylene vinyl acetate; low-density polyethylenes (density 0.915 to 0.935 g/cm³); linear-low-density polyethylenes; ultra-low-density polyethylenes (density 0.86 to 0.90 g/cm³); very-low-density polyethylenes (density 0.90 to 0.915 g/cm³); medium-density polyethylenes (density 0.935 to 0.945 g/cm³); high-density polyethylenes (density 0.945 to 0.98 g/cm³); ethylene vinyl acetates; ethylene methyl acrylates; copolymers of acrylic acid, polymethylmethacrylate, or any other polymers polymerizable by high-pressure free radical processes; polyvinylchlorides, polybut-1-enes; isotactic polybutenes; ABS resins; ethylene-propylene rubbers (EPR); vulcanized EPRs; EPDMs; block copolymers; styrenic block copolymers; polyamides; polycarbonates; PET resins; crosslinked polyethylenes; copolymers of ethylene and vinyl alcohol (EVOH); or polymers of aromatic monomers such as polystyrene; poly-1-esters; polyacetal; polyvinylidene fluoride; polyethylene glycols; or polyisobutylenes.

In another embodiment, elastomers are blended with the polymer produced by this invention to form rubber-toughened compositions. In some embodiments, the rubber toughened composition is a two (or more) phase system where the elastomer is a discontinuous phase and the polymer produced by this invention is a continuous phase. This blend may be combined with tackifiers or other additives as is known in the art.

In another embodiment, the polymer produced by this invention may be blended to form impact copolymers. In some embodiments, the blend is a two (or more) phase system with a discontinuous phase and a continuous phase. This blend may be combined with tackifiers or other additives as is known in the art.

In some embodiments invention polymers are combined with metallocene polyethylenes (mPEs) or metallocene polypropylenes (mPPs). The mPE and mPP homopolymers or copolymers are typically produced using mono- or bis-cyclopentadienyl transition metal catalysts in combination with alumoxane or a non-coordinating anion activator in solution, slurry, high-pressure, or gas-phase conditions. The supported or unsupported catalyst and activator may have substituted or unsubstituted cyclopentadienyl rings. Exxon-Mobil Chemical Company (Baytown, Tex.) produces several commercial products with such catalyst and activator combinations. These are commercially available under the tradenames EXCEED™, ACHIEVE™, and EXACT™. For more information on the methods and catalyst-activator pairs used to produce such homopolymers and copolymers,

see WO 94/26816; WO 94/03506; EPA 277,003; EPA 277,004; U.S. Pat. No. 5,153,157; U.S. Pat. No. 5,198,401; U.S. Pat. No. 5,240,894; U.S. Pat. No. 5,017,714; CA 1,268,753; U.S. Pat. No. 5,324,800; EPA 129,368; U.S. Pat. No. 5,264,405; EPA 520,732; WO 92 00333; U.S. Pat. No. 5,096,867; U.S. Pat. No. 5,507,475; EPA 426 637; EPA 573 403; EPA 520 732; EPA 495 375; EPA 500 944; EPA 570 982; WO91/09882; WO94/03506 and U.S. Pat. No. 5,055,438.

In some embodiments invention polymers are present in the above blends, at from 10–99 wt %, 20–95 wt %, 30–90 wt %, 40–90 wt %, 50–90 wt %, 60–90 wt %, 70–90 wt %. (Based upon the weight of the polymers in the blend.)

The blends described above may be produced by mixing the invention polymers with one or more polymers (as described above), by connecting reactors together in series to make reactor blends, or by using more than one catalyst in the same reactor to produce multiple species of polymer. The polymers can be mixed together before being put into the extruder or may be mixed in the extruder.

Any of the above polymers may be functionalized, which means that the polymer has been reacted with an unsaturated acid or anhydride. Unsaturated acids and anhydrides include any unsaturated organic compound containing at least one double bond and at least one carbonyl group. Representative acids include carboxylic acids, anhydrides, esters and their metallic and non-metallic salts. In some embodiments the organic compound contains an ethylenic unsaturation conjugated with a carbonyl group (—C=O). Examples include maleic, fumaric, acrylic, methacrylic, itaconic, crotonic, alpha.methyl crotonic, and cinnamic acids as well as their anhydrides, esters and salt derivatives. The unsaturated acid or anhydride is present at 0.1–10 wt %, 0.5–7 wt % or 1–4 wt %, based upon the weight of the hydrocarbon resin and the unsaturated acid or anhydride.

Tackifiers may be blended with invention polymers or with blends of invention polymers (as described above). Examples of useful tackifiers include aliphatic hydrocarbon resins, aromatic modified aliphatic hydrocarbon resins, hydrogenated polycyclopentadiene resins, polycyclopentadiene resins, gum rosins, gum rosin esters, wood rosins, wood rosin esters, tall oil rosins, tall oil rosin esters, polyterpenes, aromatic modified polyterpenes, terpene phenolics, aromatic modified hydrogenated polycyclopentadiene resins, hydrogenated aliphatic resin, hydrogenated aliphatic aromatic resins, hydrogenated terpenes and modified terpenes, and hydrogenated rosin esters. In some embodiments, the tackifier is hydrogenated. In other embodiments, the tackifier is non-polar. (Non-polar means that the tackifier is substantially free of monomers having polar groups. Some tackifier compositions limit the polar-group content to 5 wt % or less, alternatively, 2 or 0.5 wt % or less.) In some embodiments the tackifier has a softening point (Ring and Ball, as measured by ASTM E-28) of 80–40 or 100–30° C. In some embodiments, the tackifier is functionalized, which means that the hydrocarbon resin has been contacted with an unsaturated acid or anhydride. Some embodiments select unsaturated acids or anhydrides from any unsaturated organic compound containing at least one double bond and at least one carbonyl group. Representative acids include carboxylic acids, anhydrides, esters and their salts, both metallic and non-metallic. In some embodiments the organic compound contains an ethylenic unsaturation conjugated with a carbonyl group (—C=O). Examples include maleic, fumaric, acrylic, methacrylic, itaconic, crotonic, alpha.methyl crotonic, and cinnamic acids as well as their anhydrides, esters and salt derivatives. The unsaturated acid or anhydride is present at 0.1 wt %, alternatively 0.5 wt % or

1 wt %, based upon the weight of the hydrocarbon resin and the unsaturated acid or anhydride.

Invention polymers, or their blends, may further comprise a crosslinking agent. Particularly suitable crosslinking agents include those having functional groups that can react with the acid or anhydride group. Alcohols, multiols, amines, diamines, and triamines belong to a nonexclusive list of crosslinking agents. Examples of useful crosslinking agents include polyamines such as ethylenediamine, diethylenetriamine, hexamethylenediamine, diethylaminopropylamine, and menthanediamine.

Invention polymers, or their blends, may further comprise typical additives known in the art such as fillers, cavitating agents, antioxidants, surfactants, adjuvants, plasticizers, antiblock additives, color masterbatches, pigments, dyes, processing aids, UV stabilizers, neutralizers, lubricants, waxes, or nucleating agents. Typically, these additives are present in amounts well known to be effective in the art: such as 0.001–10 wt %.

Specific fillers, cavitating agents, or nucleating agents include titanium dioxide, calcium carbonate, barium sulfate, silica, silicon dioxide, carbon black, sand, glass beads, mineral aggregates, talc, clay, etc.

Effective antioxidants include phenolic antioxidants, such as Irganox 1010, Irganox, 1076 both available from Ciba-Geigy. Effective oils include paraffinic or naphthenic oils, such as Primol 352 or Primol 876 available from Exxon-Mobil Chemical France, S.A. (Paris, France) and aliphatic naphthenic oils, white oils, etc.

Effective plasticizers and adjuvants include mineral oils, polybutenes, phthalates, etc. Plasticizers include phthalates such as diisoundecyl phthalate (DIUP), diisononylphthalate (DINP), dioctylphthalates (DOP), and polybutenes.

Effective processing aids, lubricants, waxes, and oils include low molecular weight products such as wax, oil or low Mn polymer, (low meaning Mn below 5000, below 4000, below 3000, or below 2500). Effective waxes include polar or non-polar waxes, functionalized waxes, polypropylene waxes, polyethylene waxes, and wax modifiers. Effective functionalized waxes include those modified with an alcohol, an acid, or a ketone.

Some invention polymers are functionalized after polymerization. Functionalized means that the polymer has been contacted with an unsaturated acid or anhydride. Suitable unsaturated acids or anhydrides include any unsaturated organic compound comprising one double bond and one carbonyl group. Representative acids include carboxylic acids, anhydrides, esters and their salts, both metallic and non-metallic. Some useful organic compound contains an ethylenic unsaturation conjugated with a carbonyl group ($—C=O$). Examples include maleic, fumaric, acrylic, methacrylic, itaconic, crotonic, alpha.methyl crotonic, and cinnamic acids as well as their anhydrides, esters and salt derivatives. The unsaturated acid or anhydride is present at 0.1–10 wt %, alternatively 0.5–7 wt % or 1–4 wt % based upon the weight of the hydrocarbon resin and the unsaturated acid or anhydride. Specific examples include waxes modified by methyl ketone, maleic anhydride, or maleic acid. Suitable low Mn polymers include lower α -olefins polymers such as propylene, butene, pentene, hexene, etc. Some embodiments select the polymer such that it includes polybutene having an Mn of less than 1000.

Applications

Invention polymers (and their blends as described above) whether formed in situ or by physical blending are used in

any known thermoplastic or elastomer application. Examples include uses in molded parts, films, tapes, sheets, tubing, hose, sheeting, wire and cable coating, adhesives, shoe soles, bumpers, gaskets, bellows, films, fibers, elastic fibers, nonwoven materials, spunbond materials, sealants, surgical gowns, and medical devices.

Adhesives

Invention polymers or their blends can be used as adhesives, either alone or combined with tackifiers. Preferred tackifiers are described above. The tackifier is typically present at about 1 wt % to about 50 wt %, based upon the weight of the blend, more preferably 10 wt % to 40 wt %, even more preferably 20 wt % to 40 wt %. Other additives, as described above, may be added also.

Invention-polymer-based adhesives can be used in any adhesive application, such as disposable items, packaging, laminates, pressure-sensitive adhesives, tapes labels, wood binding, paper binding, non-woven materials, road marking materials, reflective coatings, etc. In some embodiments Invention-polymer-based adhesives can be used for chassis construction in disposable diapers and napkins, elastic attachment in disposable-goods, and converting, packaging, labeling, bookbinding, woodworking, and other assembly applications. Specific articles include diaper liquid-transfer layers, diaper leg elastics, diaper frontal tapes, diaper standing-leg cuffs, feminine-napkin adhesive strips and perishable product packaging. Specific applications include laminations for diaper outer covers, diaper elastic cuffs, filter materials, filter masks, surgical gowns, and surgical drapes; core stabilization for diapers and feminine-napkins; diaper chassis construction; and filtration system bonding.

The invention-polymer-based adhesives described above may be applied to any substrate. Useful substrates include wood, paper, cardboard, plastic, thermoplastic, rubber, metal, metal foil (such as aluminum foil and tin foil), metallized surfaces, cloth, non-woven cloth (particularly polypropylene cloths), spunbonded fiber, cardboard, stone, plaster, glass (including silicon oxide (SiO_x) coatings applied by evaporating silicon oxide onto a film surface), foam, rock, ceramic, film, polymer foam (such as polyurethane foam), coated substrate (such as those coated with inks, dyes, pigments), polyvinylidene chloride, etc. or their combinations. Additional useful substrates include polyethylene, polypropylene, polyacrylates, acrylics, polyethylene terephthalate, or any of the polymers listed above as suitable for blends. Any of the above substrates may be modified by corona treatment, electron beam irradiation, gamma irradiation, microwave, or silanization.

Films

Invention polymers and their blends can form mono- or multi-layer films. These films may be formed by any of the conventional techniques known in the art including extrusion, co-extrusion, extrusion coating, and lamination, blowing and casting. These films may be formed by the flat film or tubular process; afterwards they may be oriented in a uniaxial or in two mutually perpendicular directions in the film's plane. One or more of the layers of the film may be oriented in the transverse or longitudinal directions to the same or different extents. This orientation may occur before or after bringing the individual layers together. For example, a polyethylene layer can be extrusion coated or laminated onto an oriented polypropylene layer, or the polyethylene and polypropylene can be coextruded into a film, then oriented. Likewise, oriented polypropylene could be laminated to oriented polyethylene or oriented polyethylene could be coated onto polypropylene. Further orientation

could follow, if desired. Film orientation in the machine direction (MD) is typically at a ratio of 1–15 or 5–7, while orientation in the transverse direction (TD) is typically at a ratio of 1–15 or 7–9. But in some embodiments, MD and TD orientation ratios are the same.

In another embodiment, the layer comprising the invention polymer compositions (or their blends) may be combined with one or more other layers. The other layer(s) may be any of those layers typically included in multilayer films. For example, the other layer or layers may be polyolefins (such as homopolymers or copolymers of C₂–C₄₀ olefins or C₂–C₂₀ olefins) or copolymers of α -olefins and other olefins (including α -olefins and ethylene). Specific polyolefins for use as other layers include homopolyethylene; homopolypropylene; propylene copolymerized with ethylene or butene; and ethylene copolymerized with one or more of propylene, butene or hexene, and optional dienes. Specific examples include thermoplastic polymers such as ultra-low-density polyethylene, very-low-density polyethylene, linear-low-density polyethylene, low-density polyethylene, medium-density polyethylene, high-density polyethylene, polypropylene, isotactic polypropylene, highly isotactic polypropylene, syndiotactic polypropylene, random copolymer of propylene and ethylene, butene, hexene, elastomers such as ethylene propylene rubber, ethylene propylene diene monomer rubber, neoprene, and blends of thermoplastic polymers and elastomers, such as for example, thermoplastic elastomers and rubber toughened plastics.

Likewise, the other layer or layers may be polar polymers. Specific polar polymers include homopolymers and copolymers of esters, amides, acetates, anhydrides, copolymers of C₂–C₂₀ olefins (such as ethylene and/or propylene and/or butene with one or more polar monomers such as acetates, anhydrides, esters, alcohol, or acrylics). Specific examples include polyesters, polyamides, ethylene-vinyl-acetate copolymers, and polyvinyl chloride.

Likewise, the other layer or layers may be cationic polymers. Specific cationic polymers include polymers or copolymers of geminally disubstituted olefins, α -heteroatom-olefins, or styrenic monomers. Specific geminally disubstituted olefins include isobutylene, isopentene, isohexene, isooctene, isodecene, and isododecene. Specific α -heteroatom-olefins include vinyl ether and vinyl carbazole. Specific styrenic monomers include styrene, alkyl styrene, para-alkyl styrene, α -methyl styrene, chloro-styrene, and bromo-para-methyl styrene. Specific examples of cationic polymers include butyl rubber, isobutylene copolymerized with para methyl styrene, polystyrene, and poly- α -methyl styrene.

Finally, other specific layers can be paper, wood, cardboard, metal, metal foils (such as aluminum foil and tin foil), metallized surfaces, glass (including silicon oxide (SiO_x) coatings applied by evaporating silicon oxide onto a film surface), fabric, spunbonded fibers, and non-wovens (particularly polypropylene spun bonded fibers or non-wovens), and substrates coated with inks, dyes, pigments, polyvinylidene chloride and the like.

The films may vary in thickness depending on the intended application; films from 1–250 μ m thick are usually suitable. Packaging films are usually from 10–60 μ m thick. Sealing layers are typically 0.2–50 μ m. There may be a sealing layer on both the inner and outer surfaces of the film or the sealing layer may be present on only the inner or the outer surface. Additives such as antiblock additives, antioxidants, pigments, fillers, processing aids, UV stabilizers, neutralizers, lubricants, surfactants and/or nucleating agents may also be present in one or more layers in the films.

Specific additives include silicon dioxide, titanium dioxide, polydimethylsiloxane, talc, dyes, wax, calcium stearate, carbon black, low-molecular-weight resins, and glass beads. In some embodiments one or more layers may be modified by corona treatment, electron beam irradiation, gamma irradiation, or microwave. In some embodiments one or both of the surface layers is modified by corona treatment.

The films described herein may also comprise from 5–60 wt % of a hydrocarbon resin, based upon the weight of the polymer and the resin. The resin may be combined with the polymer of the seal layer(s) or may be combined with the polymer in the core layer(s). The resin softening point is 100–200° C. or 130–180° C. Preferred hydrocarbon resins include those described above. The films comprising a hydrocarbon resin may be oriented in uniaxial or biaxial directions to the same or different degrees.

The films described above may be used as stretch or cling films. Stretch-cling films are used in various bundling, packaging and palletizing operations. A number of well-known tackifying additives impart cling properties to or improve the cling properties of a particular film. Common tackifying additives include polybutenes, terpene resins, alkali metal stearates, and hydrogenated rosins and rosin esters. Corona discharge can also modify film properties.

Some polymers (such as ethylene-methylacrylate copolymers) do not need cling additives and can be used as cling layers without tackifiers. Stretch-clings films may comprise a slip layer comprising any suitable polyolefin or combination of polyolefins such as polyethylene, polypropylene, copolymers of ethylene and propylene, and polymers obtained from ethylene or propylene copolymerized with minor amounts of other olefins, particularly C₄–C₁₂ olefins. Polypropylene and linear low density polyethylene (LLDPE) work well. Suitable polypropylene is normally solid and isotactic (greater than 90% hot heptane insolubles) and has wide ranging melt flow rates (0.1–300 g/10 min). Additionally, the slip layer may include one or more, anti-cling (slip or antiblock) additives that may be added during polyolefin production blended in afterwards to improve the layer's slip properties. Such additives are well-known in the art and include, for example, silicas, silicates, diatomaceous earths, talcs, and various lubricants. These additives are typically used in amounts ranging from 100–20,000 ppm or 500–10,000 ppm by weight based upon the weight of the slip layer. The slip layer may, if desired, also include one or more other additives as described above.

Polymer products can be used for nonwovens, sealing layers, oriented polypropylene, and high-clarity thermoforming materials.

Low molecular weight varieties of high-pressure propylene homo- and co-polymers can be used for hot melt and pressure sensitive adhesives.

Invention processes can use finely divided, supported catalysts to prepare propylene/1-hexene copolymers with greater than 1.0 mole % hex-1-ene. In addition to finely divided supports, invention processes can use fumed silica supports in which the support particle size is small enough to form a colloid in the reaction media.

End Use Articles

Laminates comprising invention polymers can be used as a thermoformable sheet where the substrate is either sprayed or injection molded to couple it with the ionomer/tie-layer laminate sheet. The composite if formed into the desired shape to form the article, or composite article. Various types of substrate materials to form highly desirable articles. The

laminates can be used with plastic substrates such as homopolymers, copolymers, foams, impact copolymers, random copolymers, and other applications. Specifically, some articles in which the present invention can be incorporated are the following: vehicle parts, especially exterior parts such as bumpers and grills, rocker panels, fenders, doors, hoods, trim, and other parts can be made from the laminates, composites and methods of the invention.

Other articles can also be made, for example, counter tops, laminated surface counter tops, pool liners, pool covers, boat covers, boat sails, cable jacketing, motorcycles, snowmobiles, outdoor vehicles, marine boat hulls, canoe interiors and exteriors, luggage, clothing, fabric (combined with non-wovens), tent materials, GORETEX, Gamma-radiation resistant applications, electronic housings (TV's, VCR's and computers), wood replacement for decks and other outdoor building materials, prefab buildings, synthetic marble panels for construction, wall coverings, hopper cars, floor coating, polymer-wood composites, vinyl tiles, bath, shower, toilet applications and translucent glass replacement, sidings, lawn and outdoor furniture, appliances such as refrigerators, washing machines, etc., child toys, reflective signage and other reflective articles on roads and clothing, sporting equipment such as snowboards, surfboards, skis, scooters, in-line skate wheels, scratch resistant CD's, stadium seats, aerospace reentry shields, plastic paper goods, sports helmets, plastic microwaveable cookware, and other applications for coating plastics and metal where a highly glossy and scratch resistant surface is desirable, while not being subject to algae or discoloration.

Invention copolymers are suitable for applications such as molded articles, including injection and blow molded bottles and molded items used in automotive articles, such as automotive interior and exterior trims. Examples of other methods and applications for making these polymers and for which these polymers may be useful are described in the Encyclopedia of Chemical Technology, by Kirk-Othmer, Fourth Edition, vol. 17, at pages 748-819. When the application is for molded articles, the molded articles may include a variety of molded parts, particularly molded parts related to and used in the automotive industry, such as for example bumpers, side panels, floor mats, dashboards and instrument panels. Foamed articles are another application and examples where foamed plastics, such as foamed polypropylene, are useful may be found in Encyclopedia of Chemical Technology, by Kirk-Othmer, Fourth Edition, vol. 11, at pages 730-783. Foamed articles are particularly useful for construction and automotive applications. Examples of construction applications include heat and sound insulation, industrial, and home appliances, and packaging. Examples of automotive applications include interior and exterior automotive parts, such as bumper guards, dashboards, and interior liners.

Invention polyolefin compositions are suitable for such articles as automotive components, wire and cable jacketing, pipes, agricultural films, geomembranes, toys, sporting equipment, medical devices, casting and blowing of packaging films, extrusion of tubing, pipes and profiles, sporting equipment, outdoor furniture (e.g., garden furniture) and playground equipment, boat and water craft components, and other such articles. In particular, the compositions are suitable for automotive components such as bumpers, grills, trim parts, dashboards and instrument panels, exterior door and hood components, spoiler, wind screen, hub caps, mirror housing, body panel, protective side molding, and other interior and external components associated with automobiles, trucks, boats, and other vehicles.

Other useful articles and goods may be formed economically by the practice of this invention include crates, containers, packaging, labware, such as roller bottles for culture growth and media bottles, office floor mats, instrumentation sample holders and sample windows; liquid storage containers such as bags, pouches, and bottles for storage and IV infusion of blood or solutions; packaging material including those for any medical device or drugs including unit-dose or other blister or bubble pack as well as for wrapping or containing food preserved by irradiation. Other useful items include medical tubing and valves for any medical device including infusion kits, catheters, and respiratory therapy, as well as packaging materials for medical devices or food which is irradiated including trays, as well as stored liquid, particularly water, milk, or juice, containers including unit servings and bulk storage containers as well as transfer means such as tubing, pipes, and such.

EXAMPLES

General Preparation for the Bidentate Phenol Ligands (1 and 2)

A drop of formic acid was added to a solution of 4-allyl-2,6-diisopropylaniline (5.8 mmol) and salicylaldehyde or 3,5-dinitro-2-hydroxy-benzaldehyde (5.8 mmol) in alcohol (15 ml) and reaction was heated at 80° C. for 2 hrs. A yellow solid formed and was filtered from the solution, washed twice with cold alcohol (10 ml) and vacuum dried to yield the desired phenol ligands.

2-(2,6-diisopropyl-4-allylphenyliminomethyl)phenol (Ligand 1)

Ligand 1 was isolated as a yellow-orange solid in 97% yield. ¹H NMR (CDCl₃, 400 MHz, in ppm): δ 13.19 (s, 1H, OH), 8.30 (s, 1H, N=CH), 7.42 (t, 1H, ³J(H,H)=1.6 Hz, O—Ar—Hp), 7.35 (d, 1H, 3J(H,H)=1.6 Hz, N=C—Ar—Ho), 7.06 (d, 1H, N=C—Ar—Hp), 7.00 (s, 2H, C=N—Ar—H), 6.96 (t, 1H, O—Ar—Ho), 6.01 (m, 1H, 3J(H,H)=1.6 Hz, C—CH=C), 5.11 (q, 2H, 3J(H,H)=1.6 Hz, C=CH₂), 3.40 (d, 2H, CH₂—C=C), 2.98 (m, 2H, CHMe₂), 1.17 (d, 12H, CH₃ iPr).

2-(2,6-diisopropyl-4-allylphenyliminomethyl)-4,6-dinitrophenol (Ligand 2)

Ligand 2 was isolated as yellow-gold crystals in 95% yield. ¹H NMR (CDCl₃, 400 MHz): δ 16.27 (s, 1H, OH), 9.07 (s, 1H, N=CH), 8.50 (s, 1H, Ar—H), 8.26 (s, 1H, Ar—H), 7.10 (s, 2H, C=N—Ar—H), 5.97 (m, 1H, C—CH=C), 5.16 (q, 2H, C=CH₂), 3.43 (d, 2H, CH₂—C=C), 2.95 (m, 2H, CHMe₂), 1.24 (d, 12H, CH₃ iPr).

General Preparation for the Bidentate Phenol Ligands (3, 4, and 5)

A solution containing the appropriate allyl-substituted aniline (6.0 mmol), 5-methyl-3-tert-butyl-2-hydroxybenzaldehyde or 3-phenyl-2-hydroxybenzaldehyde (5.8 mmol), methanol (5 ml), and formic acid (0.25 ml) was prepared and stirred at room temperature for 12 hrs. A yellow solid precipitated during this time. It was filtered, washed twice with cold methanol (10 ml), and vacuum dried to yield the phenol ligands.

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2-(2,6-diisopropyl-4-allylphenyliminomethyl)-4-methyl-6-tert-butylphenol (Ligand 3)

Ligand 3 was isolated as a yellow-green oil in 92% yield. ¹H NMR (CDCl₃, 400 MHz): δ 13.41 (s, 1H, OH), 8.12 (s, 1H, N=CH), 7.26–6.98 (m, 4H, Ar—H), 6.02 (m, 1H, C—CH=C), 5.10 (q, 2H, C=CH₂), 3.39 (d, 2H, CH₂—C=C), 2.99 (m, 2H, —CHMe₂), 2.32 (s, 3H, CH₃—Ar), 1.48 (s, 9H, CH₃ tBu), 1.16 (d, 12H, CH₃ iPr).

2-(2,6-diisopropyl-4-allylphenyliminomethyl)-6-phenylphenol (Ligand 4)

Ligand 4 was isolated as a yellow solid in 95% yield. ¹H NMR (CDCl₃, 400 MHz): δ 13.68 (s, 1H, OH), 8.35 (s, 1H, N=CH), 7.71–7.05 (m, 8H, Ar—H), 7.00 (s, 2H, C=N—Ar—H), 6.00 (m, 1H, C—CH=C), 5.11 (q, 2H, C=CH₂), 3.39 (d, 2H, CH₂—C=C), 2.99 (m, 2H, CHMe₂), 1.16 (d, 12H, CH₃ iPr).

2-(2,6-dimethyl-4-allylphenyliminomethyl)-6-phenylphenol (Ligand 5)

Ligand 5 was isolated as a yellow solid in 90% yield. ¹H NMR (CDCl₃, 400 MHz): δ 13.71 (s, 1H, OH), 8.39 (s, 1H, N=CH), 7.69–7.01 (m, 8H, Ar—H), 6.93 (s, 2H, C=N—Ar—H), 5.98 (m, 1H, C—CH=C), 5.09 (q, 2H, C=CH₂), 3.37 (d, 2H, CH₂—C=C), 2.19 (s, 6H, CH₃).

General Synthetic Procedure for Allyl-Substituted Phenolato Nickel (II) Complexes (6–10)

Sodium hydride (0.2 g, 8 mmol) was added to a solution of the corresponding phenol ligand (1.5 mmol) in THF (20 ml). The mixture was stirred at room temperature for 2 hr, centrifuged, and the clear solution was transferred and removed under vacuum. This yielded a pale yellow solid residue. After washing with hexane (20 ml), the sodium salt of the corresponding ligand was obtained.

A benzene solution (20 ml) containing the sodium salt described above (1.5 mmol) and trans-[Ni(PPh₃)₂(Ph)Cl] (1.0 g, 1.44 mmol) was stirred at room temperature. After 6 hrs, the reaction mixture was filtered to remove NaCl. Hexane was slowly added to the top of the filtrate. Catalyst crystals were obtained in yields of 71–86%.

N-(salicylidene)-2',6'-diisopropyl-4'-allylanilinato triphenylphosphine phenyl nickel (II) (6) OR

2-(2,6-diisopropyl-4-allylphenyliminomethyl)phenolato triphenylphosphine phenyl nickel (II) Complex VI

Complex VI was isolated as a yellow-orange solid. Yield 0.81 g (78%). Anal. Found: C, 77.34; H, 6.44; N, 1.90; C₄₆H₄₆NNiOP requires C, 76.89; H, 6.45; N, 1.95. ¹H-NMR (400 MHz, C₆D₆), δ 8.06 (d, 1H, N=CH, J(H,P)=8.4 Hz), 7.80–6.44 (m, 26H, Ar—H), 6.02 (m, 1H, C—CH=C), 5.09 (m, 2H, C=CH₂), 4.17 (m, 2H, CHMe₂), 3.27 (d, 2H, CH₂—C=C, J(H,H)=6.4 Hz), 1.42 (d, 6H, CH₃ iPr, J(H,H)=6.8 Hz), 1.20 (d, 6H, CH₃ iPr, J(H,H)=6.8 Hz). ESI-MS: m/z 717 (M+).

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N-(3,5-dinitro-salicylidene)-2',6'-diisopropyl-4'-allylanilinato triphenylphosphine phenyl nickel (II) (7) OR

2-(2,6-diisopropyl-4-allylphenyliminomethyl)-4,6-dinitrophenolato triphenylphosphine phenyl nickel (II) Complex VII

Complex VII was isolated as a red solid. Yield 1.05 g (90%). Anal. Found: C, 68.97; H, 5.41; N, 5.10; C₄₆H₄₄N₃NiO₅P requires C, 68.33; H, 5.49; N, 5.20. ¹H-NMR (400 MHz, C₆D₆), δ 8.34 (d, 1H, N=CH, J(H,P)=2.8 Hz), 7.84–6.34 (m, 24H, Ar—H), 6.02 (m, 1H, C—CH=C), 5.12 (m, 2H, C=CH₂), 3.96 (m, 2H, CHMe₂), 3.28 (d, 2H, CH₂—C=C, J(H,H)=6.0), 1.29 (d, 6H, CH₃ iPr, J(H,H)=6.8 Hz), 1.12 (d, 6H, CH₃ iPr, J(H,H)=6.8 Hz). ESI-MS: m/z 807 (M+), 545 (M-PPh₃+).

N-(3-tert-butyl-5-methylsalicylidene)-2',6'-diisopropyl-4'-allylanilinato triphenylphosphine phenyl nickel (II) (8) OR

2-(2,6-diisopropyl-4-allylphenyliminomethyl)-4-methyl-6-tert-butylphenolato triphenylphosphine phenyl nickel (II) Complex VIII

Complex VIII was isolated as a yellow-orange solid. Yield 0.92 g (81%). Anal. Found: C, 77.90; H, 7.03; N, 1.88; C₅₁H₅₆NNiOP requires C, 77.67; H, 7.16; N, 1.78. ¹H NMR (C₆D₆, 400 MHz): δ 8.10 (d, 1H, N=CH), 7.90–6.34 (m, 24H, Ar—H), 6.04 (m, 1H, C—CH=C), 5.11 (q, 2H, C=CH₂), 4.45 (m, 2H, CHMe₂), 3.32 (d, 2H, CH₂—C=C), 2.32 (s, 3H, CH₃—Ar), 1.36 (d, 6H, CH₃ iPr), 1.26 (d, 6H, CH₃ iPr), 1.09 (s, 9H, CH₃ tBu). ESI-MS: m/z 787(M+).

N-(3-phenylsalicylidene)-2',6'-diisopropyl-4'-allylanilinato triphenylphosphine phenyl nickel (II) (9) OR

2-(2,6-diisopropyl-4-allylphenyliminomethyl)-6-phenylphenolato triphenylphosphine phenyl nickel (II) Complex IX

Complex IX was isolated as a yellow-orange solid. Yield 0.95 g (83%). Anal. Found: C, 78.88; H, 6.22; N, 1.73; C₅₂H₅₀NNiOP requires C, 78.60; H, 6.34; N, 1.76. ¹H-NMR (400 MHz, C₆D₆), δ 8.13 (d, 1H, N=CH), 7.89–6.34 (m, 30H, Ar—H), 6.02 (m, 1H, C—CH=C), 5.11 (m, 2H, C=CH₂), 4.23 (m, 2H, CHMe₂), 3.32 (d, 2H, CH₂—C=C, J(H,H)=6.4), 1.35 (d, 6H, CH₃ iPr, J(H,H)=6.8 Hz), 1.27 (d, 6H, CH₃ iPr, J(H,H)=6.8 Hz). ESI-MS: m/z 717 (M-Ph+), 455 (M-Ph-PPh₃+).

N-(3-phenylsalicylidene)-2',6'-dimethyl-4'-allylanilinato triphenylphosphine phenyl nickel (II) (10) OR

2-(2,6-dimethyl-4-allylphenyliminomethyl)-6-phenylphenolato triphenylphosphine phenyl nickel (II) Complex X

Complex X was isolated as a red crystalline solid. Yield 0.95 g (86%). Anal. Found: C, 77.99; H, 5.73; N, 1.91; C₄₈H₄₂NNiOP requires C, 78.07; H, 5.73; N, 1.90. ¹H-NMR (400 MHz, C₆D₆), δ 8.07 (d, 1H, N=CH, J(P,H)=8.4 Hz), 7.78–6.44 (m, 30H, H—Ar), 6.01 (m, 1H, C—CH=C), 5.10 (d, 2H, C=CH₂, J(H,H)=1.6 Hz), 3.19 (d, 2H, CH₂—C=C, J(H,H)=6.4 Hz), 2.53 (s, 6H, CH₃). ESI-MS: m/z 662 (M-Ph+), 400 (M-Ph-PPh₃+).

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The Ni (II) complexes are single component catalysts for ethylene polymerization or oligomerization.

Homogenous Polymerization with the
Allyl-Substituted Phenolato Nickel (II)
Self-Immobil Catalysts

A 500 ml autoclave was charged with 100 ml toluene under an atmosphere of argon. A solution of the allyl-substituted phenolato nickel(II) complexes (10–65 μ mole) in toluene (20 ml) was added to the autoclave. After purging the autoclave three times with ethylene gas, the ethylene pressure was raised to the specified value and maintained for the specified time. Polymerization was terminated by adding methanol and dilute HCl (10%). The solid polyethylene was filtered, washed with methanol, and dried at 40° C. in vacuum.

TABLE 1

| Ethylene Polymerization Data for Catalyst 9 (R ¹ = Ph, R ² = H, R ³ , R ⁴ = iPr). | | | | | |
|--|--------------------|--------|--------------|--|----------------------------|
| Run No. | Catalyst μ mol | T ° C. | Pressure atm | Activity ^a 10 ⁵ g PE/mol Ni · hr | M μ × 10 ⁻³ |
| 1 | 65.4 | 27 | 4 | 1.81 | 82.8 |
| 2 | 65.4 | 27 | 1 | Trace | |
| 3 | 65.4 | 27 | 2 | 0.93 | 129.3 |
| 4 | 32.7 | 27 | 4 | 3.14 | 96.0 |
| 5 | 15.1 | 27 | 4 | 2.41 | 372.4 |
| 6 | 7.6 | 27 | 4 | Trace | |
| 7 | 11.3 | 27 | 4 | 1.26 | 196.4 |
| 8 | 11.3 | 27 | 4 | 1.14 | 247.3 |
| 9 | 32.7 | 27 | 3 | 0.45 | 238.0 |
| 10 ^b | 32.7 | 27 | 4 | 3.70 | 171.5 |
| 11 | 32.7 | 47 | 3 | 2.23 | 74.2 |
| 12 | 32.7 | 67 | 3 | 2.00 | 4.4 |
| 13 | 32.7 | 57 | 3 | 2.18 | 11.8 |
| 14 | 32.7 | 37 | 3 | 1.81 | 265.3 |
| 15 | 65.4 | 27 | 3 | 1.30 | 87.2 |
| 16 | 49.1 | 27 | 4 | 2.07 | 31.1 |
| 17 | 65.4 | 27 | 4 | 1.32 | |

^aToluene solvent, 55 min polymerization

^b36 min polymerization

The PE produced from catalyst 9 has narrow MWD (PDI=3.1) and low branches (7 Me/1000 C by ¹³C NMR). DSC results indicate that the PE is a linear polymer with high crystallinity and high melting point.

While certain representative embodiments and details have been shown to illustrate the invention, it will be apparent to skilled artisans that various process and product changes from those disclosed in this application may be made without departing from this invention's scope, which the appended claims define.

All cited patents, test procedures, priority documents, and other cited documents are fully incorporated by reference to the extent that this material is consistent with this specification and for all jurisdictions in which such incorporation is permitted.

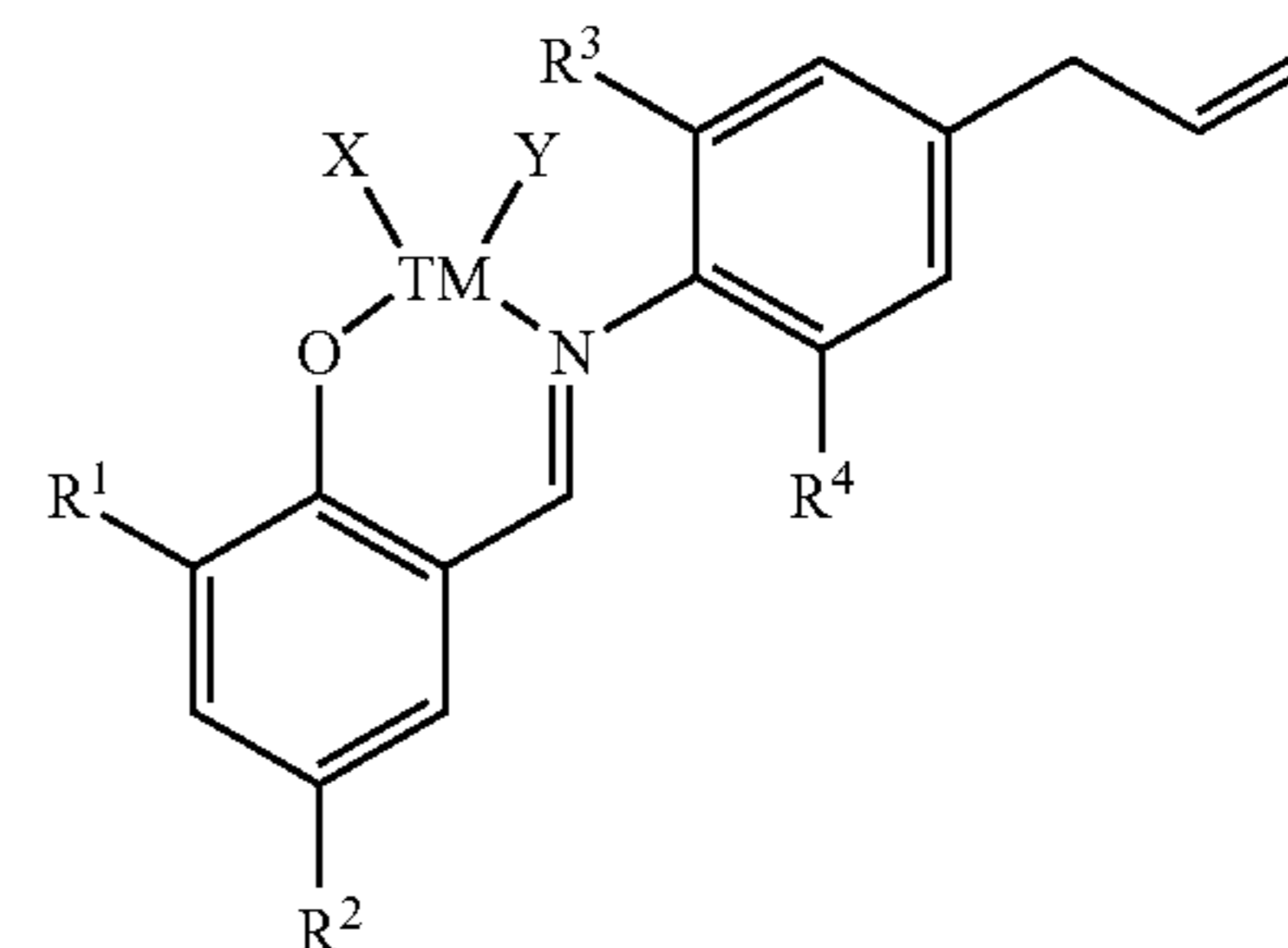
Certain features of the present invention are described in terms of a set of numerical upper limits and a set of numerical lower limits. This specification discloses all ranges formed by any combination of these limits. All combinations of these limits are within the scope of the invention unless otherwise indicated.

What is claimed is:

1. A composition comprising the product of combining, in the presence of a free radical initiator, a catalyst precursor and at least one catalyst polymerization monomer wherein

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the catalyst polymerization monomer is polymerizable by free-radical polymerization and wherein the catalyst precursor has the formula:



wherein

(a) R¹ and R² are independently hydrogen, NO₂, or hydrocarbyl groups;

(b) R³ and R⁴ are independently hydrogen or hydrocarbyl groups;

(c) TM is a Group-4–11 metal;

(d) X is an abstractable ligand; and

(e) Y is a neutral Lewis base.

2. The composition of claim 1 wherein at least one hydrocarbyl group is a C₁–C₅₀ hydrocarbyl group.

3. The composition of claim 2 wherein at least one hydrocarbyl group is a C₁–C₄₀ hydrocarbyl group.

4. The composition of claim 3 wherein at least one hydrocarbyl group is a C₁–C₂₀ hydrocarbyl group.

5. The composition of claim 1 wherein the TM is a Group-10 transition metal.

6. The composition of claim 1 wherein the TM is Ni.

7. The composition of claim 1 wherein the abstractable ligands are independently selected from the group consisting of halide radicals, hydride radicals, hydrocarbyl radicals, and hydrocarbyl-substituted, organometalloid radicals.

8. The composition of claim 1 wherein the abstractable ligands are independently selected from the group consisting of halide, alkoxide, aryloxy, amide, and phosphide radicals.

9. The composition of claim 1 wherein the abstractable ligands are independently selected from the group consisting of chloride, bromide, iodide, methyl, ethyl, propyl, butyl, pentyl, hexyl, phenyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, eicosyl, heneicosyl, docosyl, tricosyl, tetracosyl, pentacosyl, hexacosyl, heptacosyl, octacosyl, nonacosyl, triacontyl, hydride, phenyl, benzyl, phenethyl, tolyl, methoxy, ethoxy, propoxy, butoxy, dimethylamino, diethylamino, methylethylamino, phenoxy, benzoxy, allyl, 1,1-dimethyl allyl, 2-carboxymethyl allyl, acetylacetonate, 1,1,1,5,5,5-hexa-fluoroacetylacetonate, 1,1,1-trifluoro-acetylacetonate, and 1,1,1-trifluoro-5,5-dimethylacetylacetonate radicals.

10. The composition of claim 9 wherein at least one of the abstractable ligands is chloride.

11. The composition of claim 1 wherein the catalyst polymerization monomer is styrene, vinyl styrene, alkyl styrene, isobutylene, isoprene, or butadiene.

12. The composition of claim 11 wherein the catalyst polymerization monomer is styrene.

13. The composition of claim 1 wherein the free radical initiator is selected from the group consisting of azo initiators and peroxides.

14. The composition of claim 13 wherein the free radical initiator is selected from the group consisting of dialkyldia-

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zenes, hyponitrites, diacyl peroxides, dialkyl peroxydicarbonates, peresters, alkyl hydroperoxides, dialkyl peroxides, and inorganic peroxides.

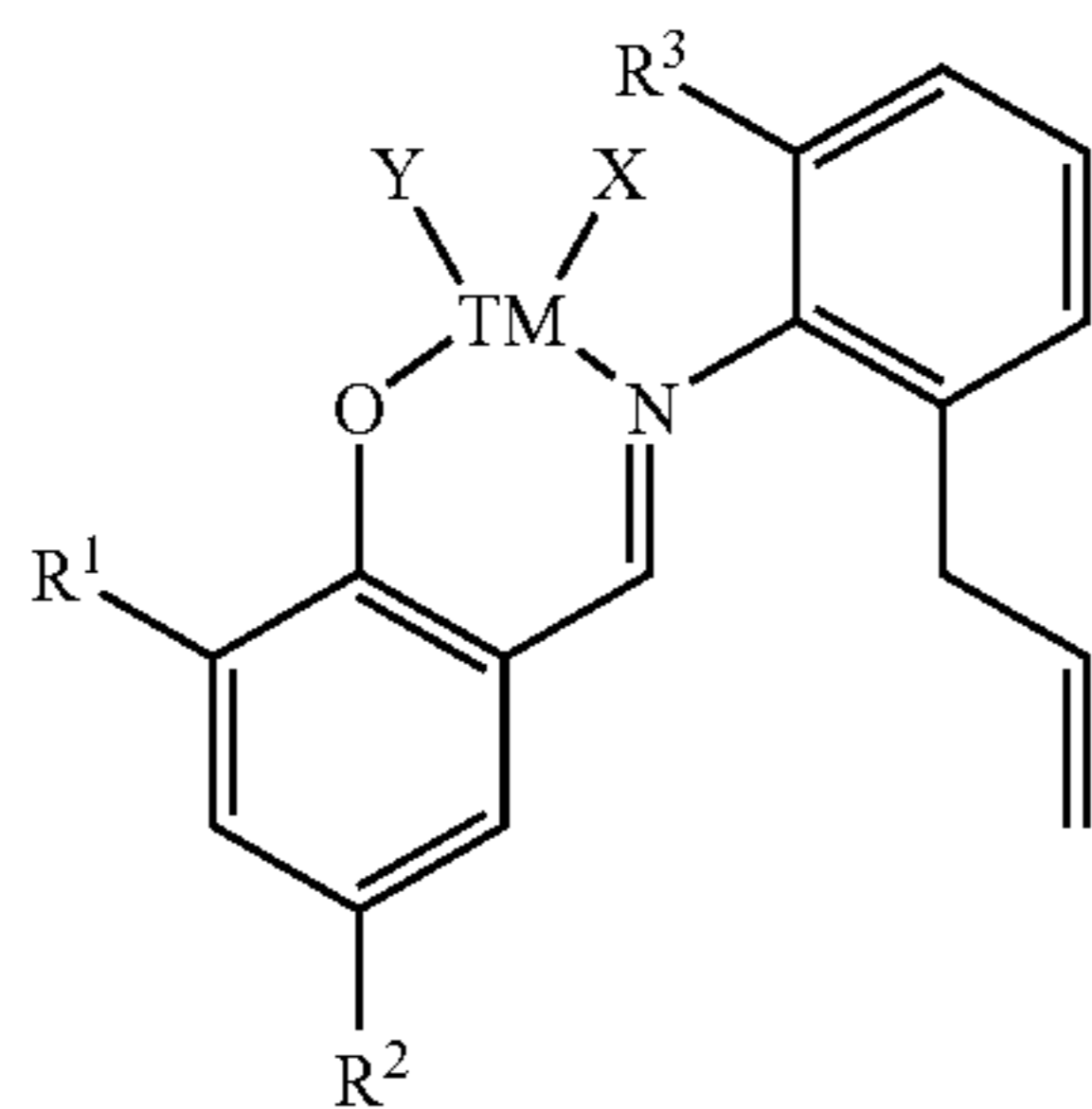
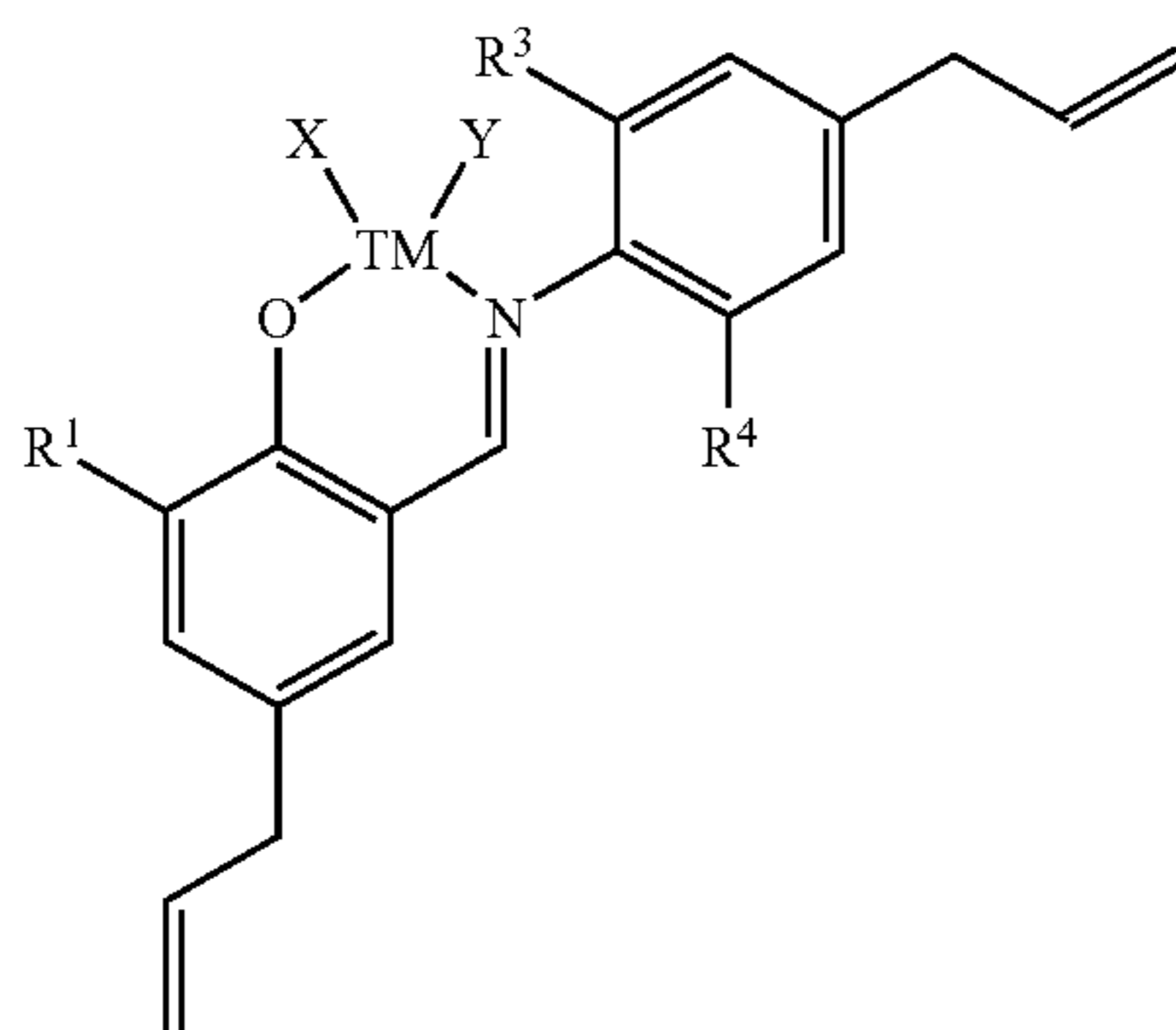
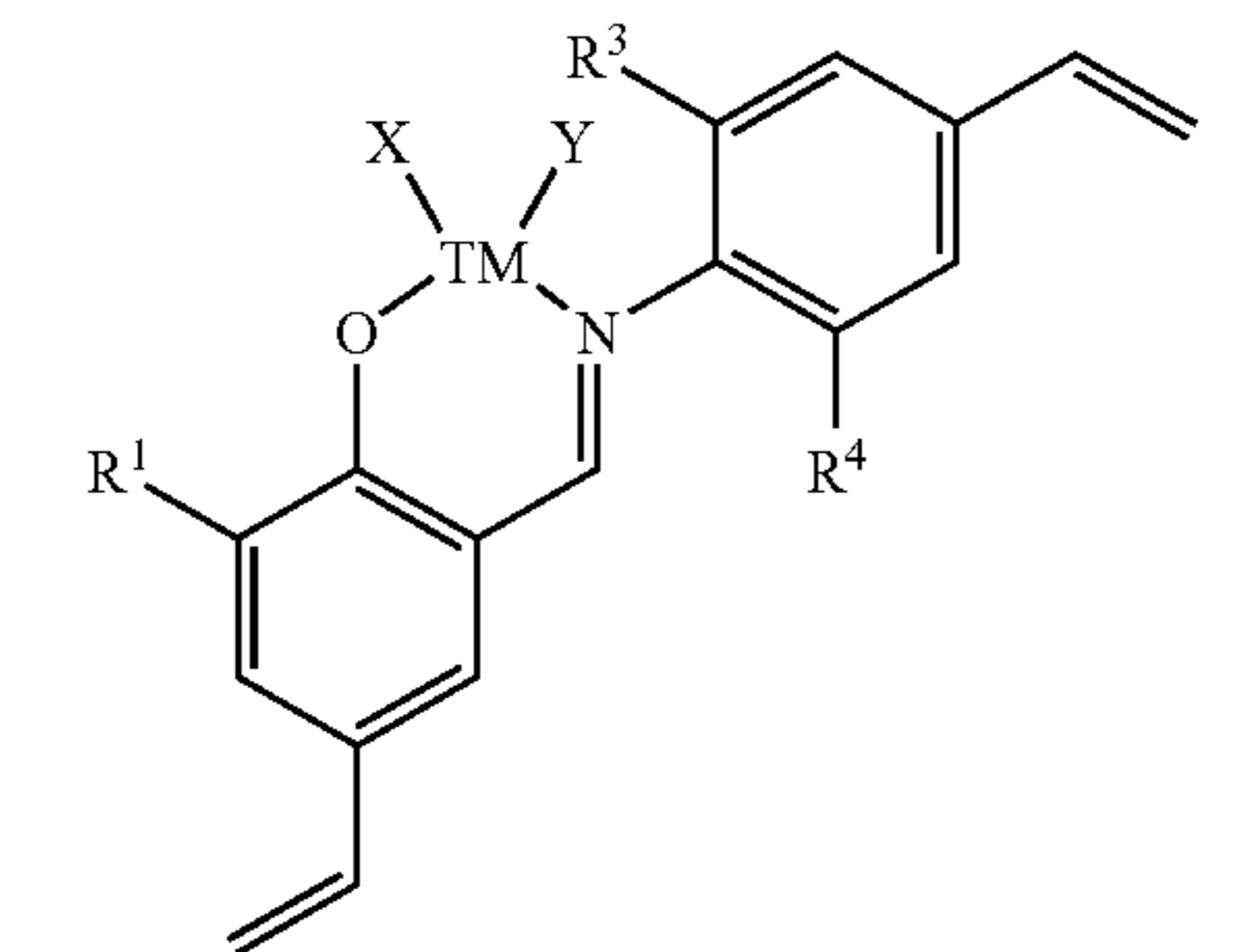
15. The composition of claim 14 wherein the free radical initiator is selected from the group consisting of 2,2'-azobis (2-methylpropanenitrile), 1,1-azobis(1-cyclohexanenitrile), 4,4'-azobis(4-cyanovaleric acid), triphenylmethylazobenzene, di-*t*-butyl hyponitrite, dicumyl hyponitrite, dibenzoyl peroxide, didodecanoyl peroxide, diacetyl peroxide, diisopropyl ester, dicyclohexyl ester, cumyl hydroperoxide, *t*-butyl hydroperoxide, dicumyl peroxide, di-*t*-butyl peroxide, hydrogen peroxide, and persulfate initiators.

16. The composition of claim 1 wherein Y is selected from the group consisting of amines, phosphines, and nitriles.

17. The composition of claim 16 wherein Y is selected from the group consisting of triphenyl phosphine and acetonitrile.

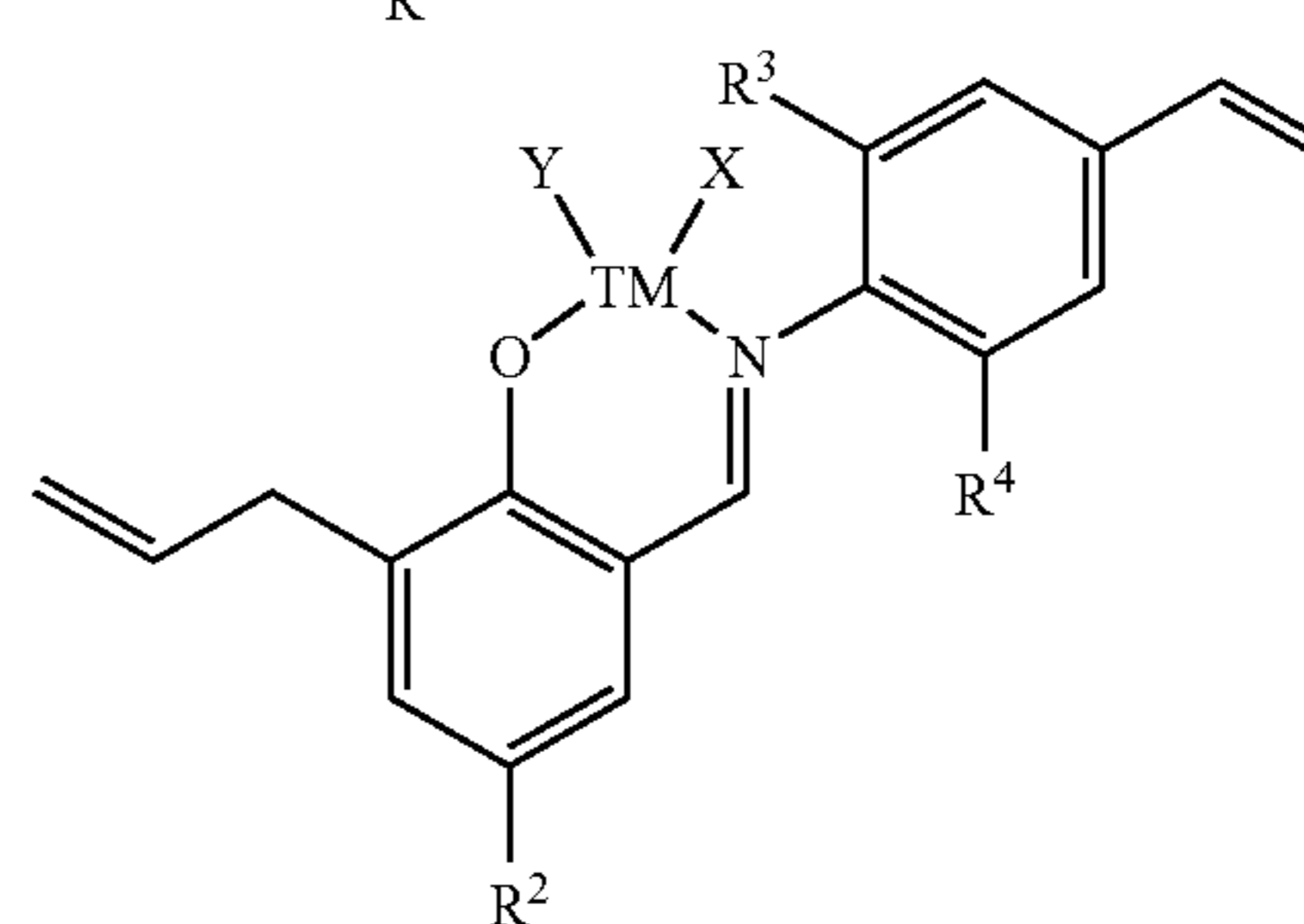
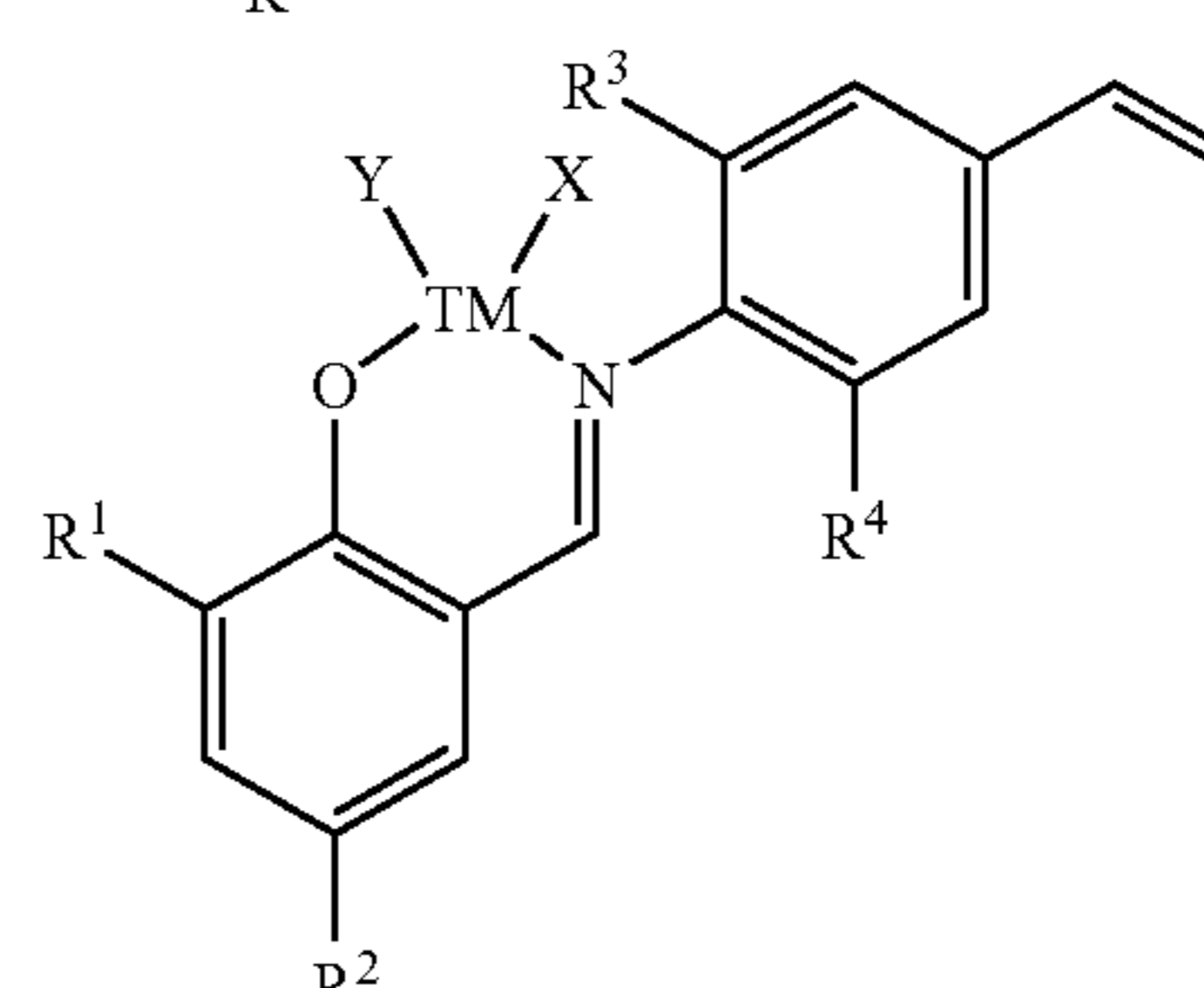
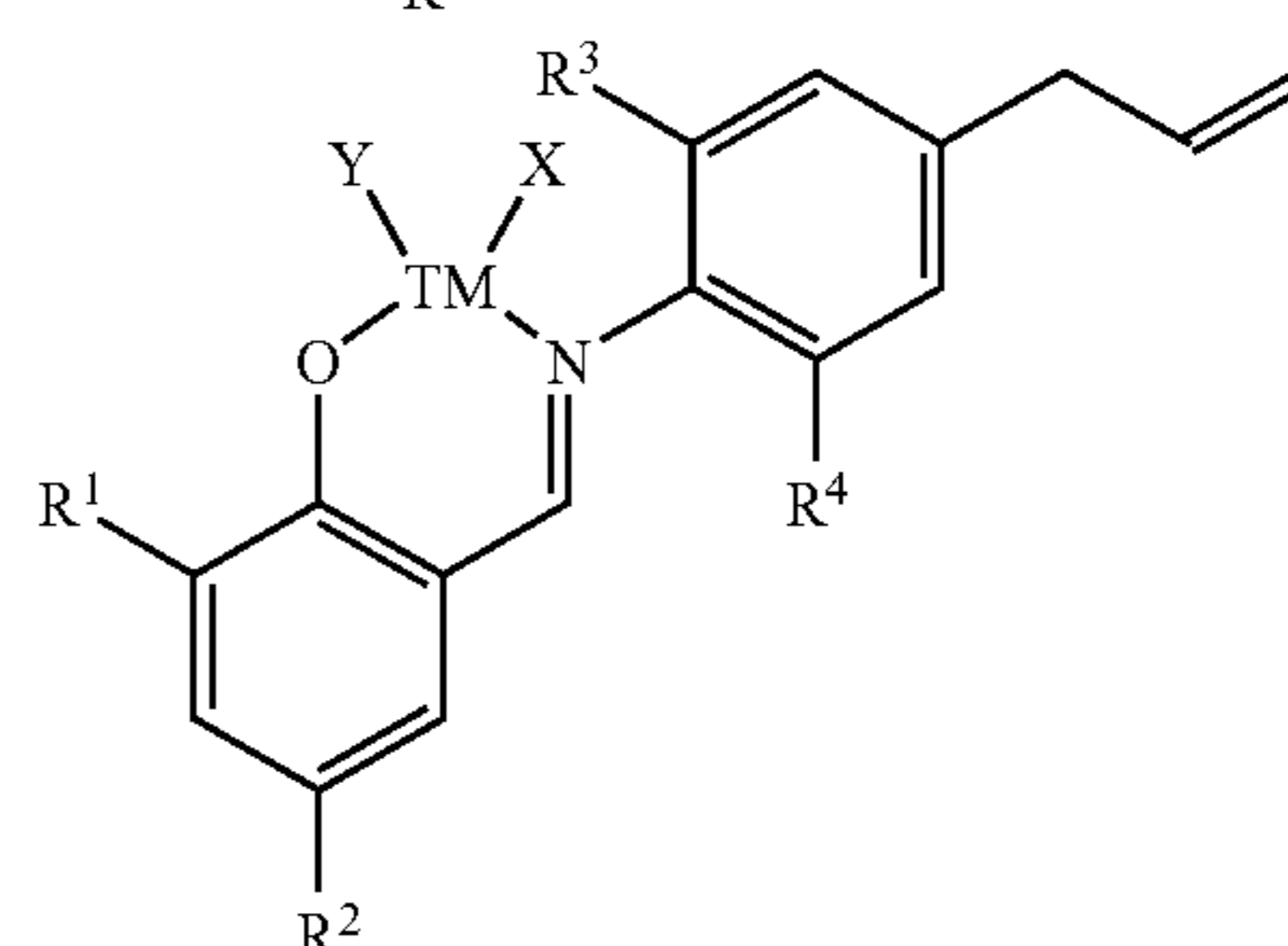
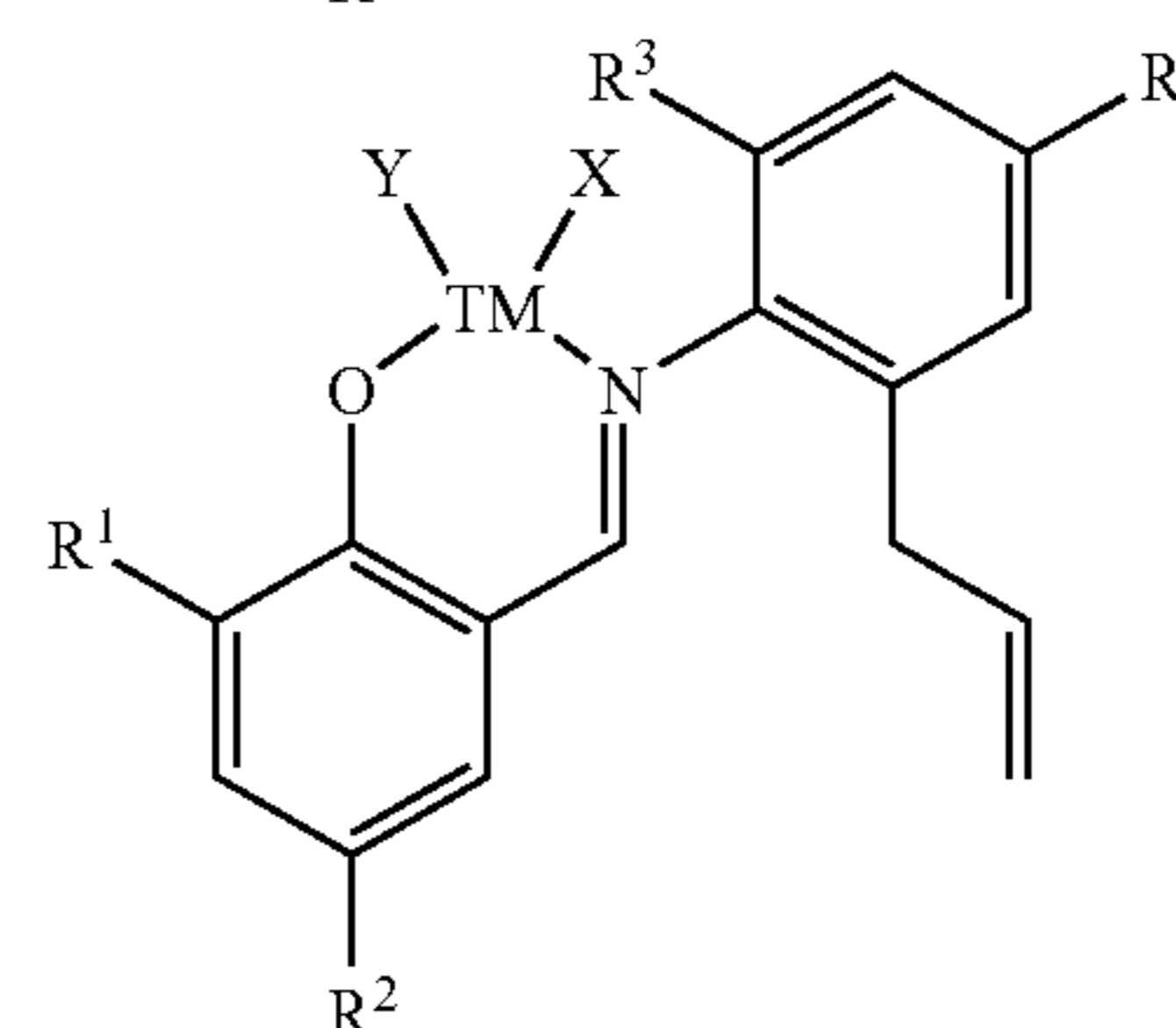
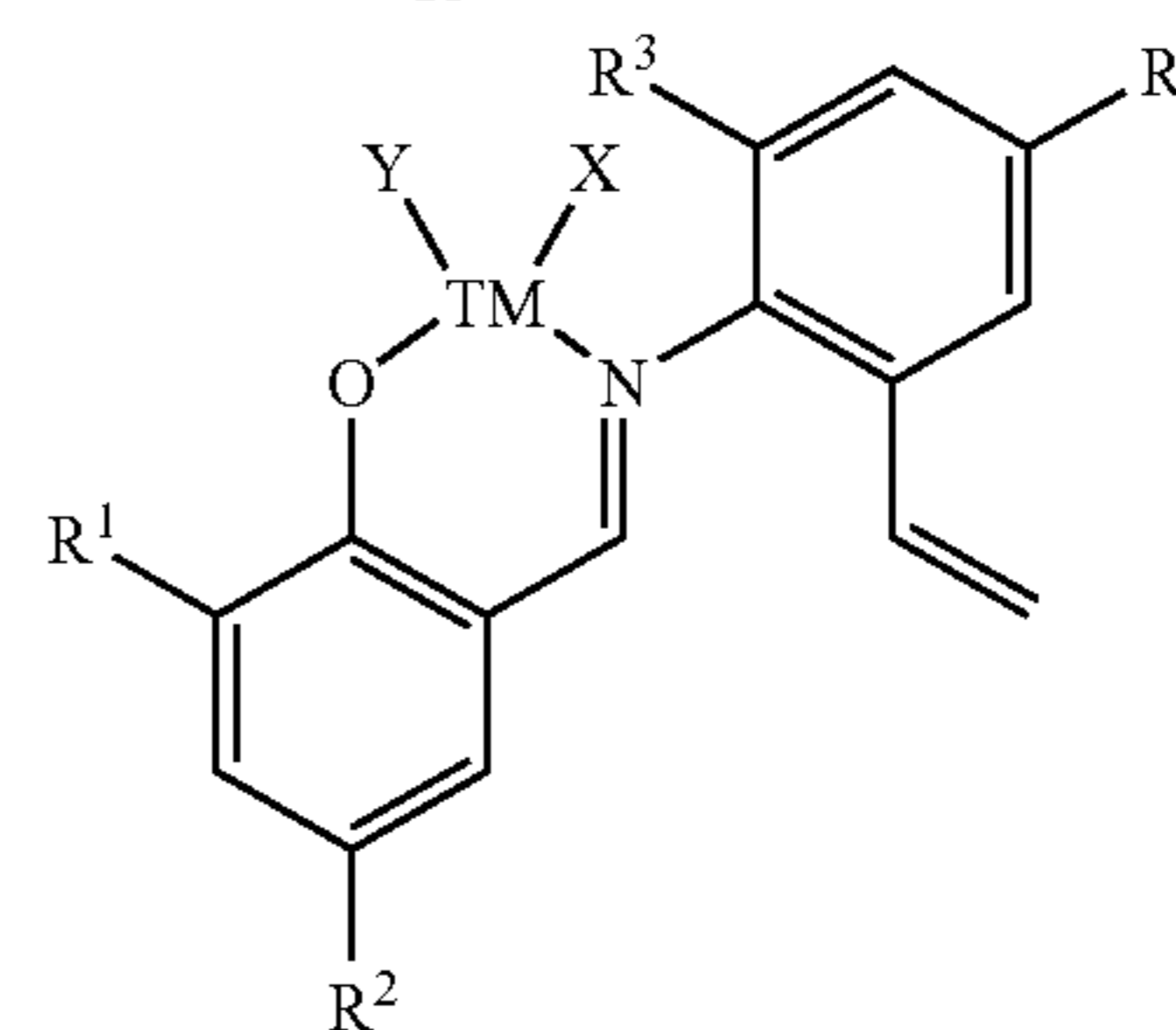
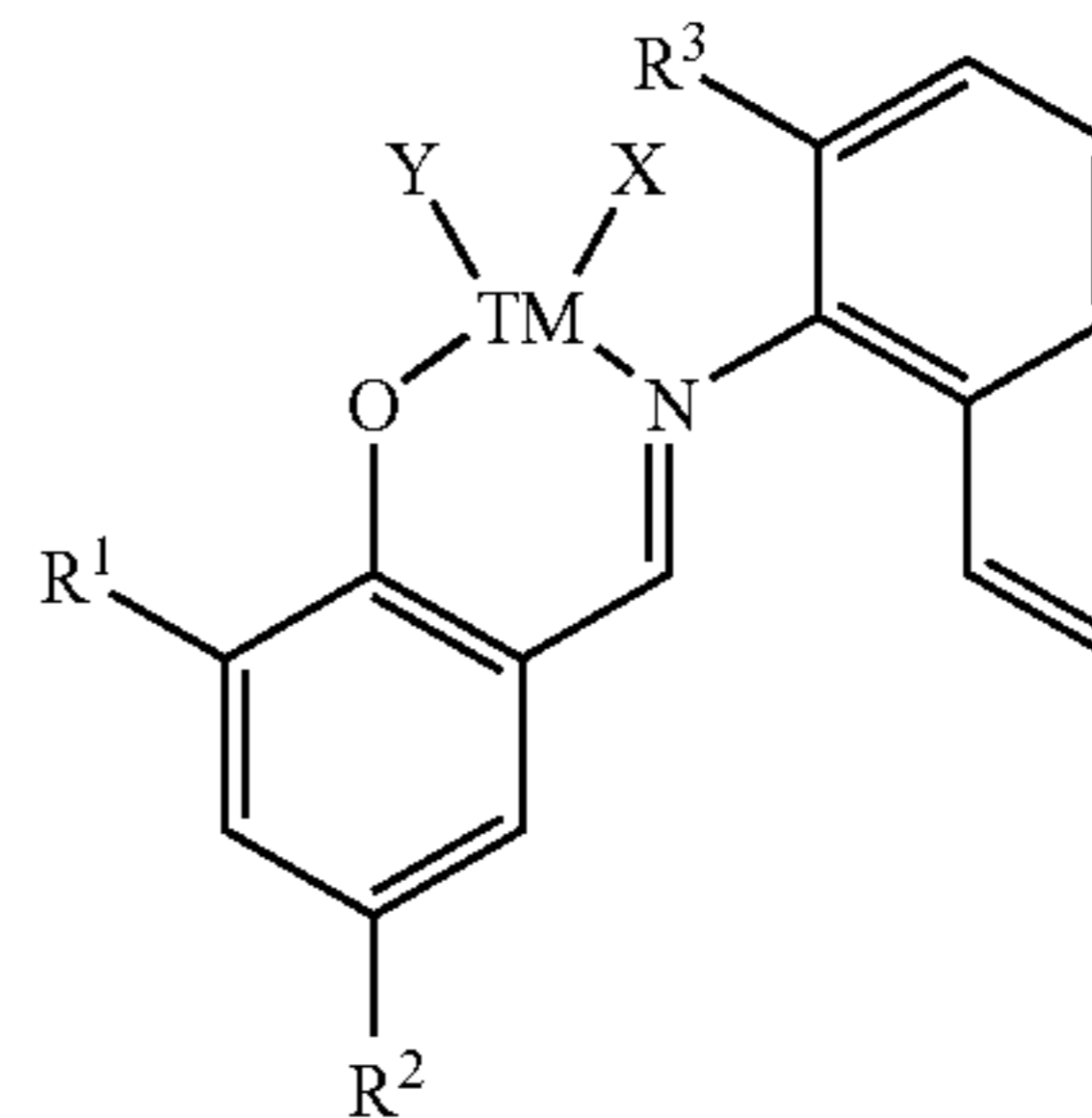
18. An olefin polymerization method comprising contacting the compositions of claim 1 with an olefin.

19. A composition comprising the product of combining, in the presence of a free radical initiator, a catalyst precursor and at least one catalyst polymerization monomer wherein the catalyst polymerization monomer is polymerizable by free-radical polymerization and wherein the catalyst precursor is represented by any one of the following structures:

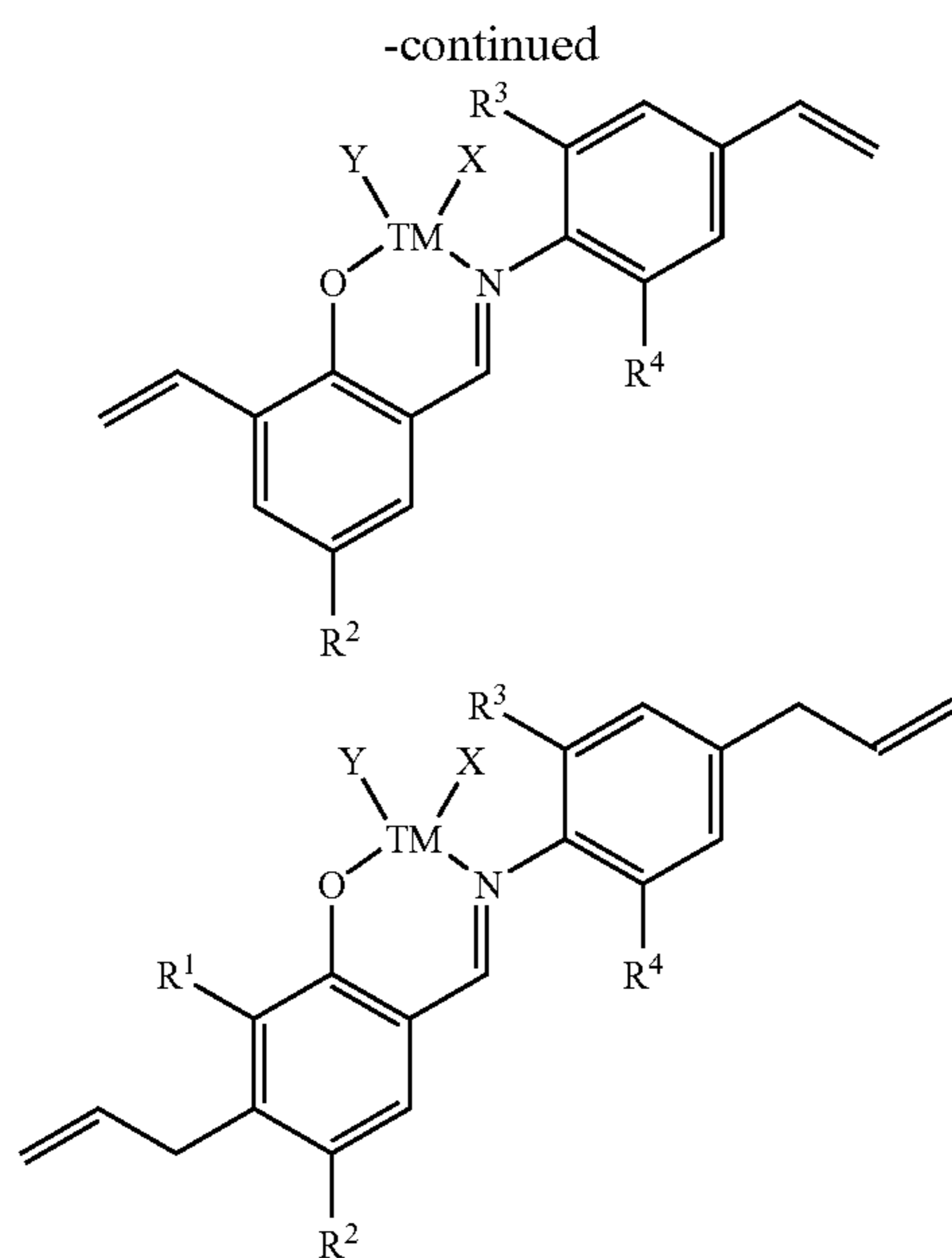


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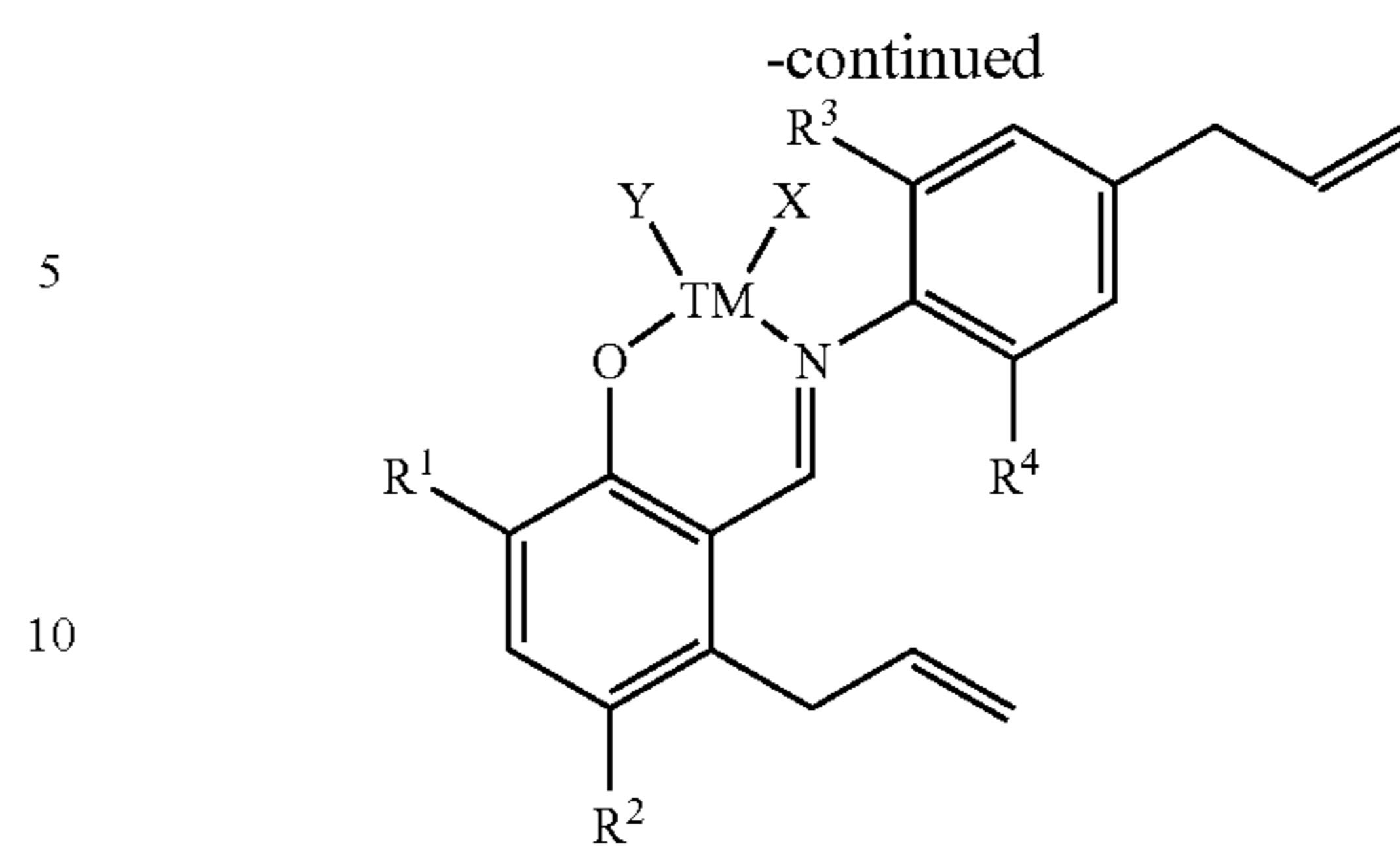
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15 wherein:

- (a) R¹ and R² are independently hydrogen, NO₂, or hydrocarbyl groups;
- (b) R³ and R⁴ are independently hydrogen or hydrocarbyl groups;
- (c) TM is a Group-4–11 metal;
- (d) X is an abstractable ligand; and
- (e) Y is a neutral Lewis base.

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